REPORT

ON THE

STATE OF THE BLOOD

AND THE

BLOOD-VESSELS IN INFLAMMATION.

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ON THE

STATE OF THE BLOOD

AND THE

BLOOD-VESSELS IN INFLAMMATION,

And on other points relating to the Circulation in the Extreme Vessels:

TOGETHER WITH

A REPORT

ON LYMPHATIC HEARTS AND ON THE PROPULSION OF LYMPH FROM THEM, THROUGH A PROPER DUCT, INTO THEIR RESPECTIVE VEINS.

BY

T. WHARTON JONES, F.R.S.

"IN YONDER WORLD, I DO BELIEVE,
THAT TRUTH THEY STILL MAINTAIN;
BUT WITH THE LIES THAT HERE PREVAIL,
OUR MARSHAL FIGHTS IN VAIN."
Bismarck.

"SHAM FAILS,
TRUTH PREVAILS."
Moltke.

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ADVERTISEMENT.

THE following pages are respectfully addressed to the General Council of Medical Education—Universities and their Colleges—Colleges of Physicians, Colleges of Surgeons, and all other Authorities, who may consider the faithful instruction of Students of Medicine in a real knowledge of the phenomena of the Circulation of the Blood to be of paramount importance.

THE AUTHOR.

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REPORT ON THE STATE OF THE BLOOD

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Introduction.

I TAKE it to be the object of Mechanics to describe the phenomena of Nature—to describe them completely, and in the simplest manner. I mean that it will be our task to state what the phenomena are, but not to find out the causes. See 'Introduction to Lectures on Mechanics,' by the late Gustav Robert Kirchoff, Professor of Physics in the University of Berlin.

> "Thus Harvey sought the truth, in truth's own book, Creation,
> Which by the hand of God Himself was writ,
> And wisely thought 'twas fit,
> Not to read comments only, upon it,
> But on the original itself to look."—*Cowley.*

About fifty years ago I contributed to the 'British and Foreign Medical Review' certain 'Reports on Inflammation,' and in 1850, there appeared in the October number of 'Guy's Hospital Reports' my Astley-Cooper Prize Essay, "On the State of the Blood and the Blood-Vessels in Inflammation, as ascertained by experiments, injections, and observations by the microscope." This Essay was supplemented with a Paper (published in the 'Medico-Chirurgical Transactions' for 1852), describing the phenomena of inflammation as it occurs in the web of the bat's wing, my previous observations having been confined to the web of the frog's foot.

Prefacing the Paper "On Inflammation in the Web of the

Bat's Wing," I observed:—"It has not unfrequently been objected to the results obtained from microscopical observations on the web of the frog in the inflamed state, that we cannot safely argue from them as to the nature of the inflammatory process in man.

"This, however, like many other general objections, is well or ill-founded according to the sense in which the terms are employed. If, in the objector's mind, the word 'inflammation' conjures up the idea of a pleurisy or pneumonia, of a meningitis or encephalitis; nay, even of a conjunctivitis or iritis, with all the attendant symptoms (subjective as well as objective), functional disturbance and terminations, I admit that the objection is well founded. But if, on the contrary, all that we venture to deduce from our microscopical observations on the web of the frog in the inflamed state be merely something concerning the general nature of the inflammatory process, something of the state of the blood and the blood-vessels in the inflamed part, something, in short, in elucidation of the question as to the *proximate cause* of inflammation, so much agitated by the pathologists of the last century, then, I apprehend that the objection is ill-founded.

"Still, there can be no doubt that, even as regards the simple elucidation of the state of the blood and the blood-vessels in an inflamed part of the human body, microscopical observations made on a transparent part of a warm-blooded mammal would be more satisfactory than similar observations on the cold-blooded reptile, especially when we take into consideration the marked peculiarity of character which the red blood-corpuscles of the mammifera present.

"Accordingly, in pursuing my researches into the nature of the inflammatory process, I have not failed to direct attention to the microscopical study of the effect of wounds on the state of the blood and the blood-vessels in the web of the bat's wing; the bat being the only mammiferous animal which presents an external part of the body thin and transparent enough for microscopical examination."

Of late years I have contributed various papers on the physio-pathology of the circulation to the 'Lancet' and the

'American Journal of the Medical Sciences.' More recently still, in a series of communications to the 'Lancet,'* in the course of the last ten years, I have commented on the misrepresentation of facts, and on the blundering excogitations relating to the subject, too often found in the text-books put into the hands of students of medicine. The aim of the present Report is to insist further on this, and to show that in the study of a science of observation, such as physiopathology, we must scrupulously direct attention to the phenomena of Nature in their sequence and correlations; while we as scrupulously refrain from excogitations. Too commonly, would-be investigators build up some plausible excogitation on what they see or think they see, nay, wish to see, and then excogitate experiments to prove this excogitation. "Nil fingendum, nil excogitandum, sed inveniendum quod Natura ferat, quod Natura faciat," is a precept which has ceased to find much acceptance among them, except when read backwards.

The State of the Blood and the Blood-Vessels in Inflammation.

§ 1. "The experimental inquiry respecting the contractile power of the blood-vessels and the Nature of Inflammation," prefixed to the Treatise on "Inflammation of the mucous membrane of the Lungs," which the late Sir Charles Hastings published in 1820, was, in my Report, No. XXXIV. of the 'British and Foreign Medical Review' (July, 1844), signalised as a valuable contribution to medical science. In it Sir Charles remarked that at the commencement of inflammation in a frog's web, the corpuscles of the blood within the vessels of the affected part appear, under microscopical observation, as if fused together into a uniform red mass which moved sluggishly along, and at last became stagnant, a condition which had been indicated by older writers in the expression of "*lentor* and *remora*." The vessels themselves,

* For a list of these communications, see Appendix.

he conceived to be "debilitated in their action," and that to this, the alteration in the condition of the blood on entering them from the vessels of the adjacent healthy part, is owing. Herein, however, Sir Charles committed himself to an excogitation in the attempt to define the cause of the phenomenon instead of tracing it out in its sequence and correlations. The expression "debilitated action," seems to be a relic of the jargon of Brunonianism.

§ 2. One kind of "debilitated action" of the arteries is exemplified in paralytic relaxation of their walls, and this is manifested by dilatation of their calibre from distension with blood now flowing freely on under the full operation of *vis a tergo*, permitted by the loss of tension; the force of the heart remaining unaltered. In a case of such *debilitated* action of arteries there is thus, associated with the dilatation of calibre, *increased* activity of the flow of blood and *not a retardation leading to stasis*. On the other hand, "increased action" of the arteries is exemplified in tonic contraction of their muscular coat, and this is manifested by more or less persistent constriction of their calibre *with impediment to the flow of blood*. Let it be asked, therefore, in which of the two cases do we find "debilitated action"? Herein is a dilemma, between the horns of which John Hunter thought he had slipped through by remarking that dilatation is as much an evidence of power as constriction of calibre from contraction of the arterial wall. If John Hunter assumed, as the late M. Paul Bert erroneously thought he had proved by experimental researches,* that dilatation of the calibre of arteries is owing to direct muscular action, he was over-hasty in his assumption. A dilemma, therefore, still remained. The rapid flow of blood in arteries, relaxed and dilated by distension, is, however, an evidence of unaltered power of the heart.

§ 3. Such dilemmata are to be guarded against by simply

* M. Paul Bert's blunders have been taken up as facts and adduced as a standard outcome of experimental research. Notably, see 'The Advancement of Science by Experimental Research': being the Harveian Oration, delivered before the Royal College of Physicians of London on June 27, 1883. By S. O. Habershon, M.D., F.R.C.P., late Senior Physician to, and Lecturer on Medicine at, Guy's Hospital.

observing and describing phenomena in their sequence and correlations, as Kirchoff advised, instead of inventing causes to account for them. Inflammation is a morbid process, the phenomena attending which have their initial seat in the blood and blood-vessels of the part affected. In studying its course, therefore, we have to direct attention to the sequence and correlations of the phenomena which present themselves in connexion with the state and action of the said blood and blood-vessels.

§ 4. In my Report on the Nature of Inflammation in No. XXXIV. of the 'British and Foreign Medical Review' (1844), I accepted the doctrine that to suspension of nervous influence from the arterioles, the accumulation and aggregation of blood-corpuscles in the extreme vessels of a part, constituting inflammatory congestion, are owing. This excogitation, however, I formally renounced in my Essay on the state of the blood and the blood-vessels in inflammation ('Guy's Hospital Reports,' October, 1850), for the reason which I proceed to explain: After directing my attention to the mechanism of the establishment of vascular congestion in a wounded part, I turned to the study of the mechanism of a vascular congestion which had become established in the web of a frog, independently of any solution of continuity of vessels by a wound. In such a case when the walls of the arteries of the limb were paralysed by section of the ischiatic nerve, I found that the congestion was rapidly dispersed by the free flow of blood which ensued under the full influence of *vis a tergo*—the force of the heart continuing unchanged—which came into operation. This, it may be observed, showed that "debilitated action" of arteries, even to actual paralysis, was a condition *antidotal to*, not *a cause of*, the idiopathic inflammatory congestion of the character under notice.

§ 5. In the case of inflammatory congestion *around a wound*, a similar resolvent effect was *not* produced. On the contrary, congestion was not only increased,* but continued

* See *infra*, and also the description of my preparations of wounded and inflamed webs of the frog, injected with their own blood, and the illustrative drawings in 'Guy's Hospital Reports,' before cited.

so, especially on the further side of the wound, and declined only as healing took place and a freer circulation of blood in the part was re-established.

§ 6. To return to non-traumatic vascular congestion :—In such a case (having its seat in the web of a frog), the application of an irritating collyrium did, indeed, cause an aggravation of the congestion by exciting the muscular walls of the arterioles to increased contraction with corresponding constriction of their calibre, but this was only temporary, being superseded by relaxation of walls with dilatation of calibre from distension with the full stream of blood now permitted to enter them, and to flow freely under the influence of *vis a tergo*. The effect of this, again, I found was dispersion of the congestion in a manner similar to that above described as taking place in a case of non-traumatic congestion, when the walls of the arteries were paralysed by section of the ischiatic nerve.

§ 7. Irritating collyria dropped into the eye for catarrhal ophthalmia cause dispersion of the congestion in like manner by promoting eventual relaxation of the walls of the constricted arteries, though aggravation of the symptoms is temporarily induced by the increased constriction at first excited, but which is superseded by dilatation from distension when the muscular walls become relaxed. Herein, it is to be remarked that the *modus operandi* of the remedy indicates at the same time the nature of the *proximate cause* of the congestion.

§ 8. Arteries which have their walls relaxed, become, as just observed, *dilated* by *distension* with the blood stream, which is full and rapid on account of the free operation of *vis a tergo*. The capillaries and venules to which the arterioles in question lead are also distended, and the flow of blood onwards in them is full and rapid likewise. Such is simple hyperæmia or vascular fulness with heat which may be well observed in a rabbit's ear, while the great central artery of the organ is in a state of relaxation; but which may be seen to become superseded by an anæmic condition with coldness, when constriction of the said artery supervenes, as it does occasionally. For details, see below.

§ 9. Idiopathic vascular congestion begins with constriction of the arterioles of the affected part, the effect of which constriction is retardation of the flow of blood in them, while regurgitation from various neighbouring anastomosing vessels, in which the circulation is still going on, takes place into the capillaries and venous radicles to which the constricted arterioles lead. The blood, being thus retarded in its course, red corpuscles are retained and aggregate together, while the saline constituent of the plasma, by virtue of its nature as a crystalloid, exudes by dialysis. The result of this separation of the saline constituent of the serum is that the red corpuscles with the fibrinous and albuminous elements of the plasma become so fused together, by virtue of their nature as colloids, that the appearance of a uniform viscous-looking red mass indicated by Sir Charles Hastings, as above mentioned, is produced. Flowing sluggishly along, this mass tends to become stagnant in the small vessels of the affected part—arterioles, capillaries, and venules. It is subsequently to the escape of the crystalloid constituent of the serum by dialysis that exudation of the colloid lymph takes place, as was shown by the late Professor Graham, Master of the Mint, in his researches on Colloids and Crystalloids. At the commencement of a nasal catarrh, the discharge from the nose is a clear saline solution; subsequently the discharge is a thick mucus.

§ 10. Though hyperæmia or simple vascular fulness from increased freedom of the flow of blood in a part owing to relaxation or actual paralysis of the arterial walls is, in its mechanism, the very opposite of inflammatory congestion which supervenes in the manner just mentioned on constriction of the arterioles of the affected part, the state of the blood and the blood-vessels in the two different cases is very generally confounded.* Accompanying inflammatory con-

* See my article in the 'Lancet' propounding the question:—"Is Dilatation of the Calibre of small Arteries a fact in Nature disclosed by experimental research to be owing to an active expansion of their walls under the influence of special *vaso-dilator nerves?*" and the remark on M. Paul Bert's experimental researches in § 2.

gestion with *stasis sanguinis*, there is, indeed, also more or less hyperæmia or simple vascular fulness in the parts adjacent to the focus of the inflammation, as I explained in my Essay in 'Guy's Hospital Reports,' in correction of the assumption that an increased quantity of blood flows in the vessels of the part which is the focus of the inflammation, whereas *stasis sanguinis* actually exists in them.

§ 11. It is to the cardiac impulses on the blood, flowing in the said relaxed arteries, dilated by distension, against the focus of inflammatory congestion, that throbbing is owing. This throbbing used to be considered a manifestation of a supposed heart-like propulsive action of the arteries. Coincident with the throbbing, and owing to the same cause, is the microscopically observable phenomenon of oscillation of the yielding but otherwise stationary mass of agglomerated and stagnant red corpuscles within the vessels. Though so obvious in respect to its incidental nature, this oscillation is often spoken of as something special in the inflammatory process. It is to be noted that the cardiac impulses under notice are not so strong as commonly supposed they should be under the influence of the degree of *vis a tergo* in operation, because much of this force is already expended on streams in branches that arise from the arterial trunk higher up and pour blood into extreme vessels in which the circulation is as yet free.

§ 12. The mistake that the flow of blood becomes slower in dilated arteries arose from confounding the dilated artery under observation as a channel receiving the stream from a narrower one, whereas, in the case in question, the flow is still from a wider channel, though into one become less narrow than before and, therefore, merely offering a less degree of impediment to the stream. We sometimes, indeed, see in the course of our observations on the phenomena of the circulation in the web of a frog, an artery with its calibre wide at one place and narrow at another alternately, in which very obvious retardation of the flow takes place when the blood is received into the wider from the narrower parts of the channel, while acceleration of the flow is seen when the

blood again enters a narrower part. This, it will be observed, is simply an exemplification of phenomena to be expected under the circumstances, in accordance with the principles of hydraulics.

Microscopical Examination of a Drop of Healthy Blood withdrawn from the Body.

§ 13. Examining microscopically a small drop of healthy blood disposed on a slide and covered with a thin plate of glass, immediately on being drawn, we see at first the red discs dispersed without order in the plasma, but in a minute or so arranged like coins in rouleaux. The steps of the transition to this orderly arrangement, in their sequence and correlations, are observed to be something in this wise: adjacent discs coming into direct contact overlap each other in files, and then slipping up on edge, become applied surface to surface. Herein, the phenomena would appear to indicate, in the first place, a slipperiness of the discs on each other, through the medium of the plasma; in the second place, a reciprocal attraction whereby they come into actual contact, surface to surface; and in the third place, direct adhesion. In my "Observations on the Blood," in No. XXVIII. of the 'British and Foreign Medical Review,' 1842, I offered it as my conclusion that the reciprocal attraction and adhesion of the red discs is of a special character, but whether of a vital or physical nature I did not stop to inquire, only observing that the phenomenon appears to be very much influenced by the state of the corpuscles, on the one hand, and the composition of the fluid in which they are surrounded, on the other. The phenomenon of the approach of the red discs to each other and the adhesion which takes place between them, subsequently to their coming into contact, it may now be stated, thanks to the valuable observations and experiments of my much esteemed friend, the late Professor Graham, Master of the Mint, depend on the peculiar nature as *colloids* of the red discs, on the one hand, and of the fibrinous constituents of the plasma in which they are suspended, on the other.

§ 14. As leading to the orderly arrangement of the red discs in aggregating above described, there is no indication of its being due to a stickiness of their surface, such as Sir Joseph Lister has vaunted to be a crucial *fact discovered by himself*, though it is really nothing more than an excogitation for the *nonce*, on his part. If there had been any stickiness, would the discs, let it be asked, not have adhered at once promiscuously, and so have become irregularly aggregated in the manner observed to take place in Professor Nasse's experiment of adding mucilage of gum containing a little salt in solution, to a drop of blood?

§ 15. The rouleaux, into which were seen to aggregate the red corpuscles in a drop of healthy blood newly drawn, and immediately examined under the microscope, exhibit, after a minute or two, a tendency to break up. Coincident with this disruption, the fibrin of the plasma is found to have become separated by coagulation and deposited on the glass slide in the form of minute granules, and extremely delicate pale fibrils shooting out from them in various radiating directions.

Microscopical Examination of the Blood within the Living Vessels.

§ 16. In regard to the correlations of the constituents of the blood in the living state within the vessels, it might be said that, owing to the proportion in which the colloid fibrin and the serum considered as a crystalloid solution, are mixed in the plasma, this constituent acts as a neutral medium for the suspension of the corpuscles; the red corpuscles being checked in the tendency they have as colloids to aggregate, on the one hand, and on the other, from floating in a loose and disorderly manner.

§ 17. In blood withdrawn from the conditions in which it is when flowing within the vessels of the living body, the correlations of the plasma and corpuscles become different, as above mentioned, thus: The red corpuscles aggregate into rouleaux, and so far separate themselves from the plasma. This is followed by resolution of the plasma into fibrin and

serum—the fibrin, as a colloid, undergoing pectization or coagulation; while the serum, being a crystalloid solution, is pressed out in a fluid state by the increasing contraction of the coagulating fibrin. In the fluid serum thus become free, the rouleaux of red corpuscles are left immersed. Supervening on this, the arrangement in rouleaux tends to be broken up.

§ 18. These phenomena may be taken to indicate that the presence of the fibrinous element in the fluid state is a condition favourable to the aggregation of the red corpuscles into rouleaux; while, on the other hand, immersion in the serum, which is a crystalloid saline solution in an albuminous colloid, set free when the colloid fibrin has been separated by pectization or coagulation, is unfavourable to the continuance of the said aggregation.*

§ 19. Conversely, it is here, in passing, worthy of being noted that, as we have above seen, and as we shall again see more particularly below, on the establishment of vascular congestion, as seen in the web of the frog's foot under microscopical examination, the red corpuscles and the fibrinous element of the plasma being left together in direct contact by the dialytic exudation of the crystalloid saline of the serum which takes place, become, owing to their nature as colloids, interfused and form the uniform viscous-looking red mass within the vessels of the affected part which is seen moving sluggishly along, and at last becoming stagnant, as above described in the quotation from Sir Charles Hastings, and which was spoken of by older writers under the expression of *lentor* and *remora* of the blood.

§ 20. But to return to the behaviour of our drop of blood, which was withdrawn from the living body. After the pre-

* In No. XXVIII. of the 'British and Foreign Medical Review' (July, 1842), the fact was stated that aggregation of the red corpuscles of blood into rouleaux does still take place in the serum after the fibrin of the plasma has been withdrawn by coagulation. It was, however, shown that the inference that the fibrin exerts no essential action in causing the aggregation must be taken with some degree of qualification.

cipitation of the fibrin of the plasma by coagulation, and the disruption of the rouleaux as above described, disaggregated red corpuscles are seen floating about, in the field of the microscope, singly and confusedly in the serum; some here and there also, perhaps, adherent at a single point to the glass slide through the medium of coagulated fibrin. In such a case, if a slight agitation be communicated to the preparation, so that a current of the serum with disaggregated red corpuscles suspended in it, is produced, those at anchor here and there, are by the stream bearing on them pressed into a pear-shape. Here it may be mentioned in passing that in a case before disruption of the rouleaux had actually taken place, I subjected the preparation to galvanic influence, and found that the albumen of the serum which remained after the precipitation of the fibrin, around the rouleaux, was coagulated so that the red corpuscles were so glued together in their aggregated state that no disruption took place.

Microscopical Examination of a Drop of Blood Newly Drawn in a Case of Inflammation.

§ 21. Turning from our microscopical examination of a drop of healthy blood, let us now direct attention to the phenomena which present themselves in a drop of blood newly drawn from a person labouring under an acute inflammation of some important organ. But first, it is to be remembered that, as was particularly shown by MM. Andral and Gavarret some fifty years ago, an inflammation may commence and run its course without any change in the state of the general mass of blood in the body; but that on the supervention of inflammatory fever the fibrinous material of the plasma becomes much increased in quantity, and the number of red corpuscles diminished.

§ 22. In exemplification of this, and the peculiar phenomena attendant on it, the following cases are quoted in abstract from my "Observations on the Blood," in No. xxviii. of the 'British and Foreign Medical Review,' 1842:—

"Case I. *Blood from a young man labouring under pericarditis.*—By the time that a small drop of blood could be transferred to the microscope and examined, the red corpuscles had already aggregated together into rouleaux. These rouleaux were seen to become quickly broken up again; this was followed, however, not by disaggregation of the discs as above described in healthy blood, but by their collection into isolated masses, dispersed in wide intervening spaces of plasma. So close was this aggregation that the red corpuseles appeared almost as if fused together.

"Case II. *Blood from a young man, aged eighteen, labouring under peritonitis.*—On immediate examination of a small drop under the microscope, the red corpuscles were seen already aggregated into rouleaux, leaving in the field wide spaces of plasma. The corpuscles appeared thinner, and as if softer than in healthy blood. Disruption of the rouleaux soon followed, and the corpuseles became collected into irregular viscous-looking red masses, as if fused into each other. To the naked eye, the drop of blood, as spread out on the glass slide, exhibited the aspect referred to below, as having been described by John Hunter to be characteristic of blood drawn from a person labouring under severe inflammation.

"Case III. *Blood from a man with pneumonia of two days' standing.*—The red corpuseles, viscid-looking on the surface, quickly ran together into rouleaux, and then, as if fused into each other, became closely aggregated into irregular masses."

§ 23. On the surface of a cupful of blood, soon after being drawn by venesection in such cases, what is called a buffy coat is formed by a separation of the plasma together with the colourless from the red corpuseles. The latter remaining at the bottom of the cup in the form of crassamentum, while the plasma with the colourless corpuseles collects at the top, and, coagulating, forms the buffy coat. In the morbid condition of the blood under notice, there is, as above mentioned, an increased quantity of fibrinous matter in the plasma, while the red corpuscles are diminished in number. At the same

time, the red corpuscles aggregate with unusual celerity and closeness. Owing to this, the operation of their greater specific gravity is increased, so that they sink before coagulation of the plasma takes place. Independently, however, of their specific gravity, a separation of the red corpuscles will take place laterally, as above mentioned, in passing, and which I here proceed to notice more in detail. A drop of inflammatory blood thinly spread out on a glass slide, or even on the blade of the lancet which has been used in performing the venesection, exhibits to the naked eye a mottled aspect—red patches on a transparent ground—owing, as seen under a microscope, to collections of rouleaux of closely-aggregated red corpuscles, dispersed about in spaces occupied with plasma alone. This fact, so far as regards the naked-eye appearance, was pointed out by John Hunter, and subsequently by the late Professor van der Kolk, of Utrecht, by whom it was signalised to be as characteristic of that state of the blood on which the formation of the buffy coat depends as the buffy coat itself when formed. The reason why, as I remarked in 1842, is that the appearance is owing to the same cause. As the blood is, in the case in question, spread out in a thin film, there is of course no sinking of the aggregated red corpuscles involved, seeing that they necessarily remain on the same level surface with the plasma from which they have separated laterally.*

§ 24. Coagulation of healthy blood is found to be retarded by the addition of a crystalloid in solution, either simple, or as it exists mixed with albumen in the form of serum which has become separated from a coagulated mass. The red corpuscles, therefore, have time to subside by gravity. But to return to the changed state of the blood drawn from a person labouring under inflammation of some important organ. In the blood, as it circulates within the vessels of the living body, the red corpuscles, which are solid colloids, and the fibrinous element of the plasma, also a

* For further particulars on this and other points above noticed, see the volumes of the 'British and Foreign Medical Review' for the years 1842, 1843, and 1844.

colloid but in a fluid state, seem to react on each other in the manner peculiar to their nature. As an indication of the effect of such reciprocal action, we may accept the fused-like condition of the surface of the red corpuscles, the unusual celerity and closeness with which they aggregate into rouleaux and other peculiarities of the phenomena observed in buffy blood, on the one hand, and on the other, the increased quantity of the fibrinous constituent in the plasma; that is, if we may accept also, as I did forty-eight years ago, the teaching of the late eminent Professors of Göttingen, my friends Doctors Wagner and Henle, viz., to quote the words of the former, that "the red corpuscles might be presumed to bear the same relation to the plasma and its normal composition as the cells of secreting glands do to the secreted fluids;" and to quote the designation applied by the latter to the red corpuscles of "swimming glandular cells."

§ 25. In my "Observations on the Blood," in No. XXVIII. of the 'British and Foreign Medical Review,' the fact was dwelt on that the red corpuscles of blood drawn from a person labouring under acute inflammation aggregate, as above mentioned, more rapidly and closely into rouleaux than is to be observed in healthy blood. Misinterpreting my words on the subject, the late Dr. Williams, in his 'Principles of Medicine,' published in 1843, attributed to me a statement "that it is a similarly rapid and close aggregation of the red discs within the vessels which is the cause of the obstruction in the capillaries in inflammation and other cases of impeded circulation." This, Dr. Williams called an "assumption" on my part, and then proceeded to refute the statement with which he had credited me by an *ignoratio elenchi*. On this, I remarked*: "How much soever the author of this Report believes that the greatly increased tendency of the red corpuscles of buffy blood to aggregate, would promote the action of the exciting cause of inflammatory stasis, it was never for a moment his opinion that such increased tendency was a necessary condition for inflammatory stasis, knowing

* Report "On the Nature of Inflammation" in No. XXXIV. of the 'British and Foreign Medical Review,' § 19, 1844.

that this may arise from a slight injury, and when the mass of blood is still quite healthy."

§ 26. In a Paper in the 'Philosophical Transactions' for 1858, entitled "On the Early Stages of Inflammation," by Joseph Lister, Esq., F.R.C.S., Eng. and Edin., Assistant Surgeon to the Royal Infirmary, Edinburgh: communicated by Dr. Sharpey, Secretary, R.S., that author too generously credited me with having been the first to explain the mode of formation of the buffy coat, thereby indirectly exposing me to the reproach of having appropriated what was due to Professors Nasse and Henle, which any one who had not seen my paper in the original, might have brought against me. In my "Observations on the Blood" in the 'British and Foreign Medical Review,' above cited, I expressed myself to the effect that the nature of the process leading to the formation of the buffy coat in inflammatory blood was first explained by Professor Hermann Nasse, of Marburg, and subsequently by Professor Henle. "More recently," it was added, "I have made some observations on the point." Here follow the observations. My claim hath this extent—no more.

§ 27. The late Dr. Williams, in his 'Principles of Medicine' (§ 205, p. 96, published in 1843), in representing and objecting to my account of the minute process leading to the buffy coat, fell into an error which I exposed in my "Report on the Changes in the Blood in Inflammation, &c.," in the 'British and Foreign Medical Review' for July, 1844. On the other hand, Sir Joseph Lister, in his paper above referred to, credited Dr. Williams with having first described and accurately figured the appearance of white corpuscles in large numbers on the inside of the walls of arterioles, capillaries, and veins. Dr. Williams's 'Principles of Medicine,' from which Lister quotes, was published in 1843. In my "Observations on some points on the Anatomy, Physiology, and Pathology of the Blood," which appeared in the 'British and Foreign Medical Review' (October, 1842)—a year before the publication of Dr. Williams's book—a detailed account of the subject is given under the heading of "Condition of the

Colourless Corpuscles in, and their passage through, the minute arteries, capillaries, and radicles of the veins." This account was drawn up from the microscopical observations I had been making at the time, but unaccompanied by any expression claiming them as a discovery on my part. On the contrary, the account was given as what I believed to be already phenomena of common observation at the time.

§ 28. To this I would invite Sir Joseph Lister's attention. Moreover, I would invite his attention to the succeeding paragraph, in which I refer to M. Poiseuille's previously published suggestion, that the indication of attraction between the colourless corpuscles and the walls of the vessels might be owing to the less rapidity of the current of blood next the vascular wall, such as was shown by M. Girard to take place when a liquid flows through a tube of small diameter.

§ 29. As to Dr. Williams's conjecture that the colourless corpuscles which we see accumulated in unusual number on the inner surface of the walls of the small blood-vessels at the commencement of inflammatory congestion in the web of a frog, and which he suggested to be the chief cause of the obstruction leading to the stagnation of the red corpuscles, are actually new formations, I remarked in my "Report on the Present State of Knowledge of the Nature of Inflammation," in No. XXXIV. of the 'British and Foreign Medical Review' for April, 1844:—"Having directed attention particularly to the point, the author of this Report can venture to maintain that the colourless corpuscles which are seen under microscopical observation, accumulated on the inner surface of the walls of the vessels, are no new formations, but that, as stated in a former number of this 'Review' (1842), they already exist in the blood,—that when the velocity of the stream is great, the colourless are carried along mingled with the red corpuscles, but that when the stream is retarded from any cause, they are seen to become disengaged from among the red corpuscles, and fall into contact with the walls of the vessels when the stream is less rapid, and rolling slowly along or actually remaining at rest, they accumulate in great numbers," lining the wall like an epithelium. The

same view of the matter, I added, had been taken by Emmert ('Beiträge zur Pathologie und Therapie,' Heft I., s. 48, Bern, 1842). Here the question suggests itself: could Professor Virchow, in formulating his view that "proliferation" is the essential characteristic of incipient inflammation, have adopted Dr. Williams's view, that the colourless corpuscles, seen accumulated within the vessels as just described, are actually new formations, and have taken them to be the manifestation of his "proliferation?"

§ 30. In my 'Observations,' in No. XXVIII. of the 'British and Foreign Medical Review,' 1842, under the heading of "Attractions and Repulsions of the red and colourless corpuscles," it is remarked:—"From the facts stated in the preceding part of this paper, it may be admitted that the red corpuscles have an attraction for each other, but little or none for the colourless corpuscles. The accumulation of the colourless corpuscles, at the inner surface of the vascular wall, was taken by Ascherson and Weber* to indicate the existence of some kind of attraction between them and these walls." Again, in my Report on the "Nature of Inflammation," in No. XXXIV., op. cit., I remarked: "When the circulation in the web of the hind foot of a frog is attentively observed under the microscope, the colourless corpuscles of the blood are seen, if the stream be slow, to accumulate on the inner surface of the wall of the vessels—principally radicles of veins—along which they slide or roll over and over, whereas the red corpuscles, which occupy the axis of the stream, are carried directly onwards. From the differences in the position, and in the mode and rapidity of progression exhibited in the case of these two kinds of blood-corpuscles, it appears that there is something of the nature of an attraction between the colourless corpuscles and the walls of the vessels, but an absence of attraction between the red corpuscles and these walls, as also between the red and colourless corpuscles themselves. Though the red corpuscles keep together in the axis of the stream, sliding on each other, there is not apparent among them any actual tendency to

* Müller's Archiv.

aggregate, such as that which is observed in blood drawn from the body and at rest, as above described.

§ 31. In very small capillaries, colourless corpuscles may be observed passing, one after the other, but a red corpuscle, only now and then—a peculiarity which suggests the idea that the phenomenon is owing, not to the difference in size (for the red corpuscles readily yield, so as to be accommodated to vessels of a width less than their own diameter), but to an absence of attraction, if not the existence of a positive repulsion, between the red corpuscles and the walls of the vessels. I have seen colourless corpuscles readily enter very small capillaries; but a red corpuscle, when it would have followed, has been as if warded off, unless accidentally pushed in by the passing stream.

§ 32. Sir Joseph Lister, as above mentioned, has excogitated the cause of the aggregation of the red corpuscles into rouleaux, which we see take place in a drop of blood newly drawn from the body and displayed under a microscope. This discovery of his, as he claims it to be, he would have us accept as a fact in nature affording the true explanation of the process of inflammation, thus:—"The essential feature," says he, "of the inflammatory process is a more or less complete suspension of a functional activity in the affected tissues (the consequence of some injurious influence acting on them) owing to which the red corpuscles of the blood in the vessels of the part acquire increased adhesiveness or stickiness of surface, and so aggregate together and block up the vessels, causing *stasis sanguinis*." The late Sir Charles Hastings' account of the phenomenon observed at the commencement of inflammation in a frog's web displayed under a microscope, viz., "the corpuscles of the blood within the vessels of the affected part, as if fused together into a uniform red mass, which is moved sluggishly along and at last becomes stagnant," is above quoted (§ 1) as a simple enunciation of what can be observed in nature; but Sir Charles' *obiter dictum* that the vessels themselves are debilitated in their action, and that to this the alteration in the state of the blood on entering them from the vessels of the adjacent

healthy part is owing, can be considered only as an excogitation.

§ 33. Sir Joseph Lister's *discovery*, so far as regards a stickiness of the surface of red corpuscles is concerned, which he considers to be the true explanation of the inflammatory process, is all his own; but excluding this excogitation, his view of the essential feature of the inflammatory process appears something like a *reproduction* of Sir Charles Hastings' account. In excogitating that the red corpuscles of the blood in the vessels of an inflamed part acquire increased stickiness of surface, Lister displays a misconception of the phenomenon of aggregation in its sequence and correlations. The adhesion and fusion into each other which take place between the disks are subsequent to their coming into contact by attraction, and are, we have seen, owing to their nature as colloids.

§ 34. The idea that the red corpuscles of the blood aggregate into rouleaux by virtue of a stickiness of their surface, and not on account of any kind of attraction bringing them together, has been strenuously combated by Professor Richard Norris of Queen's College, Birmingham. In illustration of his argument, Dr. Norris prepared a number of cork disks, loaded at one side of the circumference, so that they might float perpendicularly in a liquid he placed them in. The disks, thus suspended, ran together into rouleaux after the manner of the red disks of blood. This phenomenon, he justly concluded, must be owing to the operation of an attractive force and not to any stickiness of surface—a property which cork disks do not possess.

§ 35. It has been above shown that in a drop of healthy blood examined under the microscope immediately on being drawn, the phenomenon of the aggregation of red corpuscles into rouleaux does not indicate anything that we could admit to be the effect of a "stickiness" of their surface. The phenomenon of the aggregation of red corpuscles within the vessels, as we have seen, and shall see more particularly below, when discussing vascular congestion and the fusion of the said corpuscles into a uniform viscous-looking red mass, is still further from indicating anything like the

effect of mere stickiness. The reciprocal attraction of the red corpuscles and disposition to melt into each other at their surfaces when, by the abstraction of surrounding serum, they have been in direct contact for a time, depends on their colloid nature, as we have seen reason to conclude from the late Professor Graham's observations on Colloids and Crystalloids.

§ 36. As to the accumulation of colourless corpuscles on the inner surface of the vascular walls, all that can be said by way of description of the phenomenon has been stated above, and in my Reports in the 'British and Foreign Medical Review.' Here I would call to mind how that, in the small vessels, we see the red corpuscles keep together in the axis of the stream of plasma, *though they do not adhere to each other;* while next the walls, where the stream is slower, the colourless corpuscles tend to accumulate. This tendency of the colourless corpuscles to accumulate depends, as above suggested, on an attraction between them and the vascular walls, the operation of which is favoured, partly by the slowness of the stream next the walls and partly by an attraction between them and the plasma, such as we see manifested by their continuing mingled therewith in the formation of the buffy coat. We shall see below that red corpuscles acted on by solution of salt applied to the web show an attraction for the wall of a vessel which they do not exhibit under normal conditions.

§ 37. At the commencement of the establishment of inflammatory congestion, colourless corpuscles accumulate, in the manner just mentioned, on the inner surface of the walls of the vessels, while the red corpuscles, which are retained, aggregate. Hereupon the crystalloid element of the serum in solution separates and is exuded by dialysis. The fibrinous element of the plasma which is left, and what of the albuminous element of the serum which has not exuded along with the crystalloid solution, coalesce, by virtue of their colloid nature, with the colloid red corpuscles, and thus there is produced the well known aspect of a viscous-looking red mass which moves sluggishly along in the

vessels, and at length, becoming stagnant, blocks them up. It is subsequently to the dialysis of the crystalloid saline in solution that the exudation of the colloid in the form of lymph takes place, as was shown by Mr. Graham.

§ 38. The colloid fusion of the red corpuscles into each other in the stagnant blood increases in degree the longer the stasis exists. If the conditions for the resolution of vascular congestion come into operation before stasis has existed long, re-establishment of the circulation in the vessels concerned I observed to take place in the following manner:—At every stroke of the heart, the mass of aggregated red corpuscles was pushed onwards, and what of it was forced into neighbouring anastomosing vessels in which the circulation was going on was quickly disaggregated and carried away in the stream. When, however, the stasis had already existed for some time, the tenacity with which the red corpuscles were held together by the fusion was so great that it was only after repeated impulses that the stagnant mass was moved on in portions into the neighbouring vessels and carried away in the stream.

Coagulation of the Blood.

§ 39. The colloid fusion of the red corpuscles in *stasis sanguinis* just spoken of is not an example of coagulation similar to that which we see the blood undergo a few minutes after being drawn from the body. In my observations on some points in the "Anatomy, Physiology and Pathology of the Blood," in No. XXVIII. of the 'British and Foreign Medical Review,' 1842, it is stated that, as well known, the blood, a few minutes after being drawn from the body, coagulates into a red jelly-like mass, and that, by the slow shrinking in volume which this mass undergoes, a yellowish liquor is gradually squeezed out.

§ 40. The crassamentum and serum into which the mass of coagulated blood thus becomes resolved, consist, it is to be noted, of the components of the blood while circulating in the vessels, and for a short time subsequently to its being

drawn, but altered as regards condition, combination and arrangement. The transition of the blood from the liquid state into that of a red jelly-like mass is owing to the pectization or coagulation which the fibrinous material of the plasma comes to undergo by virtue of its colloid nature. From this pectization or coagulation, there results a felt-work of fibres, in the meshes of which the corpuscles (both red and colourless), together with the serum (left separate when the fibrinous material of the plasma underwent pectization), are retained. If it is by virtue of its colloid nature that this fibrinous material of the plasma undergoes pectization, how is it, it will be asked, does pectization not take place in the blood within the vessels of the living body?

§ 41. Within a time as short as that during which blood continues uncoagulated after abstraction, the blood within the vessels of the living body has already made two or three circuits, in the course of each of which it has become impregnated with carbonic acid gas on the one hand, and deprived of oxygen gas on the other while passing through the capillaries of the system; to be, conversely, in its passage through the capillaries of the lungs, impregnated anew with oxygen gas and freed from the carbonic acid gas with which it had become loaded in passing through the capillaries of the system. Furthermore, the blood, in its course through the body, receives the renovating lymph, but gives out various matters for nutrition and secretion, while in exchange certain decomposed old matters are returned, to be eventually eliminated from the system in various processes.

§ 42. The blood in its course within the vessels of the living body is thus in a state of constant change as regards composition, like the tissues themselves which it nourishes, while it is itself object and agent of its own nutritive changes. Indeed, it has been aptly compared by a French Physiologist to a tissue under the name of *Chair coulante*. The blood in fact, though fluid, contains in suspension (as remarked in my "Observations" in the 'British and Foreign Medical Review,' No. XXVIII., 1842), innumerable organized

and living corpuscles, endowed with properties by virtue of which the oxygen and lymph which are being constantly received into the blood are elaborated, with generation of heat, into material fitted to supply what is lost in the waste of the body. While the blood is thus the medium of nutrition for the body, it is the agent by which it is itself maintained in the state and condition fitted for the purpose; the state of fluidity, for example, which depends on a constant renewal of its composition, whereby the tendency to pectization of the fibrinous material of the plasma is constantly superseded.

Coagulation of the Blood within the Vessels.

§ 43. Having thus traced the phenomena attending the coagulation of the blood after abstraction from the body, in their sequence and correlations, and endeavoured to explain how it is that the blood in its normal state within the vessels of the living body maintains its fluidity, it is now to be stated that under certain abnormal conditions, local intravascular deposits of coagulated fibrin do take place from the blood. This, therefore, remains a subject of study.

§ 44. The following is a description of the beginnings of the internal clot which came to be formed in the case of a wound of the web of a bat's wing dividing an artery, as represented in a drawing before me which I made at the time. Haemorrhage having become arrested by the formation of an external clot, the upper segment of the divided artery from its mouth thus closed to some distance above was seen filled with blood. The red corpuscles of this blood having become aggregated, formed a deposit of crassamentum in the part of the interior of the arterial stump in question, next the orifice now stopped up by the external clot, chiefly on one side of the wall, while on the other side of the wall and extending higher up to where the stream passed off from the trunk of the vessel, under the influence of *vis a tergo* by the first considerable branch above the wound, plasma collected. Herein was exemplified a separation of the blood collected

within the upper segment of the vessel into crassamentum and plasma, something like what occurs in the formation of the buffy coat. It may be mentioned, in passing, that the internal clot thus formed received successive additions of plasma by deposit from the stream passing off from the trunk of the vessel by the first considerable branch above the wound.

§ 45. The blood, though within a living vessel, thus undergoes coagulation in consequence of being at rest, and, therefore, excluded from the changes which normally take place in its composition while circulating through the body. Sometimes in the course of my observations, I have seen the part of the upper segment of the divided artery containing the internal clot suddenly become constricted, whereupon, the crassamentum and the plasma composing it, as above mentioned, were regurgitated into the stream passing off from the trunk by the considerable branch above and carried away.

§ 46. From blood within a vessel in full stream, a local deposit of fibrinous matter is found where there may happen to be a lesion of the inner coat of the vessel. This cannot be compared to the coagulation exemplified in the formation of the internal clot just described. It may, however, be compared to the coagulation exemplified in the formation of the external clot; thus, when an artery is divided, the cut ends retract within its sheath, the inner surface of which at the place is thereby left ragged by the laceration and stretching of the cellular tissue. The blood escaping from the mouth (the *upper* let us say) of the cut vessel, encounters this ragged inner surface of the sheath, and thereon fibrinous matter from the plasma is deposited by coagulation, and forms the external clot whereby further haemorrhage is arrested, and the condition established for the accumulation of the blood which comes to form the internal clot as above described. The deposit of fibrin from blood just drawn from the body on being whipped or stirred may be compared, in one respect, to the deposit just described on the ragged inner surface of the sheath of a divided artery.

§ 47. In frogs, of which one of the feet was the seat of ulceration and slough, I have frequently seen while examining under the microscope the circulation going on in the other foot, which was healthy, agglomerations of red corpuscles, followed by fibrinous floccules, intermixed with leucocytes, suddenly present themselves in an artery, in the form of an embolon. After an instant or two, these emboli becoming more or less disintegrated and reduced in size, were forced onwards by *vis a tergo*. Such emboli appear to be internal clots which have formed in small arteries leading to parts where congestions of blood were seated, and which, being regurgitated by the contraction of these vessels in the direction of their trunks, were received into the torrent of the circulation and carried away. They seem to be of a nature similar to that of the emboli met with in the human body after operations; but different from that of a thrombus arising from fibrinous deposit in cases of lesion of the inner coat of an artery. By making pressure with a blunt point over an artery or vein in the web of a frog or bat displayed under the microscope, the inner coat of the vessel is bruised, the effect of which injury we see to be a deposit, at the place of the lesion inside the vessel, of a grayish granular floccule, consisting of white corpuscles held together by a fibrinous-looking viscid substance. By this thrombus the calibre of the vessel, which has at the same time undergone constriction from contraction of the muscular wall excited by the pressure, is further obstructed. See below, § 72.

§ 48. Hewson pointed out that by dissolving sulphate of soda in blood as it flows from a vein, coagulation is prevented, so that the red corpuscles readily subside; but that if the plasma thus left at the top in a fluid state be poured off and mixed with water, it is found to coagulate. This is owing to the dilution of the sulphate of soda solution. In a similar manner, ammonia mixed with blood as it flows from a vein prevents coagulation, but by-and-by the volatile alkali escaping, coagulation takes place. Again, admixture with serum, which has separated from a cupful of blood, interferes with coagulation, the serum in such a case, it is

to be noted, acts merely as a saline solution. Though blood may be thus kept fluid, after being abstracted from the body, it cannot be compared, in respect to composition, to blood actually circulating within the vessels.

Phenomena Attending the Establishment of Vascular Congestion as Excited by Different Causes.

1. *Phenomena attending the establishment of vascular congestion in a wounded part of the web of a frog's foot or bat's wing.*

§ 49. In my Essay on "The State of the Blood and Blood-Vessels in Inflammation" ('Guy's Hospital Report,' for October, 1850), I described and illustrated by drawings from the life the phenomena attending the establishment of vascular congestion in a wounded part of a frog's web, as observed under the microscope. Subsequently, in a paper in the 'Medico-Chirurgical Transactions,' for 1852, I described the corresponding phenomena in the web of a bat's wing.

§ 50. In a wound of the web of a frog's foot or bat's wing, involving division of a small artery, this vessel was seen to become constricted on either side of the section for some distance beyond, so that the blood was driven *centrad* in the upper segment and squeezed onward *distad* in the lower. In a few seconds, the constriction of the vessel ceasing, in consequence of relaxation of its muscular wall, which had become contracted at the place under the stimulus of the wound, *vis a tergo* came freely into operation, and haemorrhage took place from the upper segment in a direct course. On the stoppage of this haemorrhage by the formation of an external clot, the upper segment of the divided artery, from its mouth thus closed to some distance above, was seen filled with blood, which came to be the nucleus of an internal clot, as above explained. What haemorrhage took place from the lower segment of the divided artery was by reflux. After its cessation, blood,

of which the red corpuscles had separated from the plasma, remained filling the interior of the vessel down to the origin of a branch in which a retrograde stream was sluggishly moving. This collection of blood, though analogous to the nucleus of an internal clot, as just described in the upper segment, differed somewhat in the mechanism of its formation.

§ 51. The mouths of the capillaries and venous radicles actually divided in the wound became stopped up with aggregated red corpuscles. In passing, it may be remarked that under none of the conditions now described was any migration of white corpuscles outwards seen, notwithstanding that the mouths of the divided vessels were otherwise open.

§ 52. The capillaries and venous radicles previously fed by the extreme ramifications of the divided artery, gradually became gorged and dilated by distension with blood corpuscles in consequence of regurgitation into them from anastomosing capillaries and venous radicles to which collateral arterial channels unimplicated in the wound directly led, such, for example, as the arterioles from the considerable branch above the wound by which the stream of blood was passing off from the trunk.

§ 53. Into the extreme ramifications of the divided artery themselves below the wound, a reflux of blood took place from the capillaries previously fed by them, but now, as stated, supplied by regurgitation, so that the said extreme arterial ramifications likewise became gorged and dilated by distension, this being permitted by the relaxation of their muscular walls which had ensued.

§ 54. The blood thus regurgitated into the extreme vessels of the part not being driven on freely in this retrograde course, the red corpuscles accumulated by retention and aggregated together, by virtue of their colloid nature, into a uniform viscous-looking red mass (in the manner above explained, § 37), which came to block up the capillaries, the arterioles leading to them, and the venules proceeding from them.

§ 55. In a drawing before me (which I made from nature) of the state of the blood in the capillaries of the bat's wing at

the beginning of arrestment of its free flow, the red corpuscles are represented as aggregated in a manner similar to what we see in blood newly drawn from the human body, viz., some in a linear series overlapping each other, in one vessel, and, in another vessel, some arranged in a single long roll, occupying the lumen of the capillary vessel.*

§ 56. From the description now given of the mechanism of the establishment of vascular congestion in a wounded part of the frog's web, it will be understood how it is that on the further side of the wound, chiefly, the accumulation of the blood in the capillary network, the arterioles leading to it, and the venules proceeding from it, commences ; this being due, not to any increased afflux of blood directly to the place, but to a retention of the blood corpuscles slowly received into the vessels by reflux from adjacent anastomosing vessels in which the circulation was going on. Hence it is that when the arterial trunk higher up is relaxed and the flow of blood in it is accelerated by the freer operation of *vis a tergo*, the congestion by regurgitation from the neighbouring vessels fed by it, in which the circulation is free, becomes augmented.

§ 57. Considering the great quantity of blood which thus becomes accumulated in the vessels on the further side of a wound, we may comprehend how it is that haemorrhage by reflux is so liable to take place from the mouth of the lower segment of divided vessels, and how, in consequence of its retrograde and sluggish flow, the blood escapes without any rhythmical impulse. In haemoptysis, the haemorrhage is owing to some such state of matters. In a case of chronic bronchitis aggravated now and then by weather influences, the sputa after coughing are streaked with blood. On one occasion, after a violent fit of coughing, a great mouthful of blood was expectorated. Such occasional aggravations of the symptoms I interpret as owing to an increased constriction of bronchial arterioles with increased congestion of the small

* For delineations of the red corpuscles within the small vessels of the frog's web tending to aggregate and become fused into each other, when there was more or less impediment to the flow of blood, see Plates IV., VI., and VII., in my Essay in 'Guy's Hospital Reports,' October, 1850.

vessels by reflux. Some of these vessels giving way under the strain of coughing, blood escaped in the quantity mentioned. By this, irritation was for the time relieved, and resumption of a freer circulation took place. In cases of actual lesion implicating arterioles, congestion by reflux takes place in a somewhat similar manner, as will be understood from the descriptions of vascular congestion here being given. In the case of the proximal segment of a divided artery, the direct stream, as before said, passes off by the first considerable branch above the wound; hence, *vis a tergo* now extends but comparatively little to the mouth of the segment, so that the formation of an external clot is the less resisted.

2. *Phenomena attending the establishment of vascular congestion as observed in a part cauterised by being touched with a point of nitrate of silver or blue-stone.*

§ 58. In 'Guy's Hospital Reports,' so frequently cited, I showed that when the web of a frog, displayed under a microscope, was slightly touched with a point of lunar caustic or blue-stone (the latter by preference, as nitrate of silver causes opacity at the place) over an artery, contraction of the muscular wall of the vessel was excited and constriction of its calibre thereby induced, with the effect that a check was given to the free flow of blood. The contracted state of the muscular coat of the artery, however, quickly ceasing, constriction gave way to enlargement of calibre by distension with blood in a full stream. This dilatation of the artery by distension with blood in a full stream was not of long continuance, however, but was superseded by a new constriction, this time to gradual obliteration of the calibre of the vessel at the place, which proved to be permanent—an effect which was owing to degeneration of the structure of the wall of the artery to a mere cord, occasioned by the caustic in solution having at last penetrated thereto. With the dilatation by distension of the artery in the first instance from relaxation of its muscular wall, there was an accelerated flow of blood, causing general vascular fulness of the part,

but when the artery thus became slowly constricted to obliteration at the cauterised spot, the blood, no longer finding a passage onwards, flowed off freely by the first considerable branch above from the trunk, as in the case of stoppage of the passage by section of an artery.

§ 59. As in this case of stoppage of an arterial passage by section of the vessel, there also took place reflux of blood into the capillaries and venous radicles, as well as into the arterioles opening into the capillaries of the region to which the now obliterated artery had led. The corpuscles of the blood, thus regurgitated, were seen to become aggregated and stagnant. Neighbouring arteries which had not come under the caustic action of the bluestone, but which were merely irritated by the weak solution of it which had reached them by diffusion around, having their walls subsequently relaxed, became dilated by distension with the full streams of blood now freely entering them. From these rapidly flowing currents, the vessels, on the *distal* side of the obliterated part of the cauterised artery, received the blood by regurgitation; but the corpuscles of this regurgitated blood becoming aggregated and stagnant, the freedom of the streams in the relaxed and distended arteries adjacent was diminished owing to diversion of the flow into other channels higher up. And thus was established in a circumscribed spot intense vascular congestion from stasis of red corpuscles, owing to arrest of the flow of blood to the spot, in consequence of the obliteration of the artery leading to it. The mechanism of this congestion, it will be observed, is substantially similar to that of the congestion before described as taking place in a wounded part in which an artery is divided.

§ 60. The flow of blood in full stream causing vascular fulness in the first instance, which was owing to the enlargement of the calibre of the artery by distension with blood as before described, it is to be observed, had nothing to do with the establishment of the subsequent circumscribed congestion, and much less had any imaginary primary active dilatation of the artery.

§ 61. The explanation here given of the phenomena observed

in the experiment of touching the web of a frog with blue-stone over an artery, is, in all essential particulars, applicable to the late Professor Cohnheim's experiment of cauterising the tongue of a frog or toad with a small crystal of the nitrate of silver. The account, however, which he gives of the phenomena and mechanism of the establishment of the vascular congestion thereby excited, betrays very imperfect observation of the effects of the cauterisation of the vessels of the part and the flow of blood therein, in their sequence and correlations. Although Cohnheim suspected that the caustic gives rise to some alteration in the structure of the wall of an artery, he did not ascertain the nature of the supposed alteration, his observation of the sequence and correlations of the attendant phenomena being defective, and his experiments aimless and inconclusive.

§ 62. The experiment of cauterising the tongue of the frog or toad has been elaborately repeated by Mr. F. Darwin, among others of Cohnheim's numerous followers; but I have no hesitation in applying to him the same strictures which I have just made on Cohnheim's own work, and would here, again, declare the alleged primary dilatation of the small arteries to be a mere fancy excogitated from imperfect observation, and, of course, also the allegation that such constitutes the first step towards the establishment of the focus of vascular congestion in acute inflammation.

3. *Phenomena attending the establishment of inflammation in a non-vascular structure, as exemplified in Keratitis.*

§ 63. In my Report in the 'British and Foreign Medical Review,' No. XXXIV., April, 1844, on the present state of knowledge of the nature of inflammation, I devoted a section (No. VIII.) to the consideration of the inflammatory process in non-vascular structures. In such parts, morbid actions may go on, I remarked, in all respects similar to those which attend or result from inflammation of ordinary vascular parts. The cornea, for example, though it is vascular while being developed, is, in its fully formed and healthy state,

non-vascular, and yet inflammation of it is spoken of under the name of Corneitis, or 'Keratitis.'

§ 64. The cornea derives the materials necessary for its nutrition by exudation from the blood circulating in the vessels of the adjoining conjunctiva and sclerotica. Let us, therefore, inquire what takes place in the cornea when it suffers such an injury as would excite inflammatory congestion in a vascular part. First of all, then, the vessels of the adjoining parts of the conjunctiva and sclerotica, though not directly implicated in the injury, become the seat of congestion; and secondly, the cornea becomes more or less opaque in consequence of exudation of lymph into the interstices of its substance. Thus, the cornea when wounded, though it does not itself become the seat of vascular congestion, becomes the seat of another and most important part of the inflammatory process, viz. exudation of lymph. The only peculiarity in respect to the cornea, as compared with vascular structures, being that the vascular congestion on which the exudation of lymph depends, is seated—not in it—but in parts adjacent to it; hence, instead of the old formula, "*ubi stimulus, ibi fluxus,*" it would, strictly speaking, be more appropriate to say, in respect to Keratitis, "*hic stimulus, ibi fluxus.*"

§ 65. In the course of a *Keratitis*, the cornea may, indeed, become vascular itself also, but such an event is secondary, and is owing to the development of new vessels shooting out in the exuded lymph from those of the conjunctiva and sclerotica which became primarily congested. Such supervening vascularity in the cornea, however, does not always occur, even in the healing process. Ordinarily, the incision of the cornea for the extraction of a cataract unites by the first intention without the development of new vessels in its substance, and we sometimes see an ulcer of the cornea become filled up with non-vascular granulations.

§ 66. In Keratitis, we have thus a natural analysis of the phenomena of the inflammatory process in its two great initiatory stages—the congestion in one place, and the supervening exudation in another. Moreover, we have a well-defined example of the mode in which irritation may be

communicated to the vessels of the conjunctiva and the sclerotica, independently of any direct lesion. In a vascular part the irritation might operate directly on the vessels themselves or on the blood, but in the case of the cornea there is neither vessel nor blood to be directly acted on.

§ 67. The mode in which the vessels of the conjunctiva and sclerotica are affected in consequence of irritation applied to the cornea alone, is this: the excitement of the sensitive nerves of the cornea is transmitted to their centre, and thence by reflex action to the vaso-motor nerves of the arterioles of the adjoining part of the conjunctiva and sclerotica, so that contraction of the muscular walls of those vessels with corresponding constriction of their calibre is induced, and the consequence of this is impediment to the free flow of blood, followed by retention of red corpuscles, which become aggregated and stagnant in the manner above described as taking place in the establishment of congestion, in an ordinary vascular structure.

§ 68. Morbid action may, however, commence in the substance of the cornea itself independently of any injury from without, or of any preceding congestion of the vessels in the adjacent conjunctiva and sclerotica, though, subsequently, the irritation to which the sensitive nerves of the idiopathically affected corneal substance are thereby subjected, will be transmitted, as in the case of a wound, to the vaso-motor nerves of the arterioles of the neighbouring conjunctiva and sclerotica, whereby congestion in the vessels of these structures will be induced. A similar process may no doubt take place in a vascular structure without any primary implication of the vessels.

§ 69. In the Report in the 'British and Foreign Medical Review,' from which the statements just made are quoted, I accepted the doctrine that excitement of the sensitive nerves of the cornea by the irritation of a wound of the corneal substance, called forth "*antagonistically*," according to the late Professor Henle's view, a state of depression or temporary paralysis of the vaso-motor nerves of the muscular walls of the arterioles opening into the capillary network of the con-

junctiva and sclerotica adjoining the cornea, and that the consequence of this was relaxation of the muscular walls of the arterioles permitting dilatation of their calibre by distension, owing to the increased afflux of blood directly into it. This view, however, I subsequently renounced as above mentioned and explained (§ 4).

§ 70. In conclusion of these remarks on the vascular congestion attending Keratitis, I beg to repeat what I have elsewhere insisted on, that it is a mere excogitation to say that white corpuscles migrate from vessels of the conjunctiva or sclerotica, by boring through their walls, into the interstices of the corneal substance. It is impossible to examine the parts concerned during life. Having, however, displayed a minute section of a detached piece of healthy cornea under a microscope armed with a one-eighth of an inch object-glass, no corpuscles were at first seen on examination; but after a brief interval of time I observed white cells begin to protrude as if from interstices at the edge of the section. Such corneal corpuscles are, no doubt, the objects which Cohnheim appears to have imagined to be colourless corpuscles of the blood which had emigrated from the vessels in the adjacent parts of the conjunctiva and sclerotica, and which, as he supposed, made their way into and through the interstices of the cornea by means of amœboid movements.*

4. *Phenomena attending the establishment of vascular congestion independently of any lesion of structure.*

§ 71. In my Essay, "On the State of the Blood and Blood-Vessels in Inflammation" ('Guy's Hospital Reports' for

* In my Articles in the 'Lancet,' "On the alleged Escape of White Corpuscles from the small Vessels," I have sufficiently shown the unsatisfactory characters of the observations of Cohnheim, his predecessors, and followers, on the subject. In a reproduction of Lister's "theory" of inflammation, in a valuable text-book on Surgery, it is stated (to the bewilderment, I fear, rather than the enlightenment of the students) that the said "theory" was not received until Cohnheim's discovery of migration in 1867. I do not know if Lister has yet observed the phenomenon which at one time he had failed to see, though not to doubt. Failing his attestation, however, Mr. Victor Horsley describes emigration from a vein in the mesentery of the frog which had been exposed for *seven hours!*

October, 1850), it is mentioned that in the frog's web displayed under a microscope, we sometimes see in the course of our observations a case in which arterioles are much constricted at some particular spot, so that the current of blood in them is impeded or altogether arrested. The capillaries, previously supplied by the said arterioles, however, are seen to receive blood by reflux from neighbouring anastomosing vessels in which the circulation is going on. Interruption to the direct passage of blood in the extreme vessels of a part, thus resulting from constriction of arterioles, operates in a manner similar to that which we have found to be occasioned by actual division of an arteriole in a wound. In the web of a bat's wing I have seen a state of congestion arise under similar conditions.

§ 72. Constriction of the calibre of an arteriole for the purpose of demonstration may be at once excited by making pressure over the vessel by means of a blunt point, so as to induce contraction of its muscular coat. In connection with this, it is to be mentioned that besides the constriction of the calibre of the vessel thus occasioned, a grayish granular floccule, consisting of white corpuscles held together by a viscid fibrinous-looking substance, was deposited inside the vessel at the place of lesion by the bruise of its inner coat. The thrombus thus produced added still further to the obstruction of the calibre of the vessel.* The double effect of bruise over an artery in the forms of constriction of its calibre and of the grayish lymphy-looking deposit on the inner surface of the wall at the place pressed upon, I pointed out, firstly, in the frog in 1850, and, secondly,

* In a bat's wing, the artery being closely accompanied by a vein, both vessels suffered from the pressure, and in the interior of each a similar grayish, lymphy-looking deposit was thereby caused. It is to be noted, however, that while the artery became constricted at the place, as before described in the frog, the vein did not. In regard to this, the question arises: Did the absence of constriction of the vein depend on the difference in respect to the character of the irritability of the muscular coat of the walls of the two kinds of vessels as manifested by the difference in the phenomena of their contractility, and in respect to the difference in the microscopical characters of the fibres of their muscular coat?

in the bat in 1852, by pictorial delineation as well as verbal description.

§ 73. In the mechanism of the establishment of vascular congestion independently of any solution of continuity of vessels, simple arterial obstruction operates, as above said, in one respect like the division of vessels in a wound. Different, however, from the congestion, hereby occasioned, congestion from simple arterial obstruction, in what manner soever excited, may become resolved in the early stage by the supervention of relaxation of the contracted walls of the arteries, so that the full stream of blood which ensues under the influence of *vis a tergo*, distends the calibre of the arterioles and drives onward the aggregated mass of red corpuscles stagnant in the extreme vessels. In exemplification of this, it has been above shown (in §§ 5, 6, and 7) that in catarrhal conjunctivitis, the small arteries are constricted, while the capillary network and venules leading therefrom are the chief seat of engorgement with red corpuscles. On the other hand, it was shown that stimulating collyria in the treatment of catarrhal ophthalmia act by the relaxation of the arterial walls and re-establishment of the free flow of blood, superinduced on the cessation of the contraction of the muscular wall at first excited. The nature of the condition of the vessels implicated in the inflammation in question and the *modus operandi* of the stimulating collyrium applied in the treatment are thus reciprocally illustrative. In respect to this *modus operandi* of stimulating collyria in the treatment of catarrhal ophthalmia, it is to be noted that, as will be seen below, the vascular injection produced by a lesion—even such as is made by a thorn or the stitch of a suture—instead of being dispersed, is increased by the application of an irritant to the interdigital web of a frog or by section of the sciatic nerve, because direct *vis a tergo* in the arteries, which have been implicated, cannot be re-established while the reflux from adjacent anastomosing vessels is augmented.

5. *Phenomena attending the establishment of vascular congestion and stasis in the web of a frog's foot, excited by the application of a strong solution of common salt thereto.*

§ 74. This effect depends partly on the state of the blood-vessels thereby induced, viz. contraction of the muscular coat of the arterioles with constriction of their calibre, followed by relaxation with supervening dilatation by distension with blood; but chiefly on the action of the salt on the blood itself, through endosmose. In my Essay, "On the State of the Blood and Blood-Vessels in Inflammation" (already repeatedly cited), I described and delineated how a red corpuscle was here and there seen to strike against the wall of a capillary, whereupon others joined it, so that the vessel became obstructed by an accumulation of red corpuscles. Herein the red corpuscles and the wall of the vessel had become altered by the salt in respect to the non-attraction which, as a rule, subsists between them.

§ 75. It has been above mentioned that in a case of congestion in the frog's web, unaccompanied by any wound of the vessels, if the ischiatic nerve be cut so that the walls of the arteries of the foot are relaxed by paralysis of their muscular coat, the congestion is rapidly dispersed by the force of the fuller stream of blood in them which ensues. On the other hand, I referred to the experiment of a German physiologist,* which I had repeated, that in a frog's web congestion and stasis could not be so readily induced as usual in the extreme vessels by the application of a strong solution of salt when the ischiatic nerve had been previously divided, as when the limb is uninjured, and the circulation is going on naturally. In such a case as the former, in which the ischiatic nerve has been previously divided, so that the muscular walls of the arteries of the part have become

* I regret that I cannot here give the name of this observer. I have, however, mentioned it elsewhere on a previous occasion. At present, I have no opportunity of refreshing my memory.

paralysed and cannot contract under the stimulus of the salt solution, their calibre remains dilated by distension with blood which flows so rapidly in full stream that it escapes the action of the salt.

§ 76. In a case in which the ischiatic nerve has not been interfered with, and in which, therefore, the arteries of the web retain their contractility, the application of a strong solution of salt excites contraction of their muscular coat with corresponding constriction of their calibre, the effect of which is an impeded flow of blood. This is, however, quickly superseded by a free flow owing to the relaxation of the arterial walls with dilatation of their calibre by distension which supervenes. As the impediment from the temporary contraction is not great in the larger arteries, the full stream of blood passes on and escapes any strong action of the salt, but in arterioles, capillaries, and venules, the stream of blood, in consequence of its tenuity, is readily affected by the salt, so that here and there accumulation of red corpuscles with *stasis sanguinis* becomes established, and resists the impulse of the stream in larger arteries leading to them which have recovered from the constriction primarily excited by the stimulus of the saline solution, and in which, therefore, the flow is free. In the arterioles leading to the capillaries, thus first obstructed, stasis by-and-by becomes established also, while the streams which lead to them pass off by considerable branches above. We thus see that under the conditions now described, stasis is propagated backwards from the capillaries to the arterioles, and resists *vis a tergo* in arteries higher up, in which the blood is flowing in full streams. This, it is to be particularly noted, is no indication that congestion under other conditions, such as those which I have specially described, is not owing to constriction of arterioles, and cannot co-exist with a free circulation higher up. This and such-like blundering strictures which Sir Joseph Lister (under the misguiding auspices of his Professor of Physiology, the late Dr. Sharpey, who was at the same time Physiological Secretary of the Royal Society) has levelled against my Essay, "On the State of the Blood and the Blood-Vessels in

Inflammation," * betrays a neglect of research by observation of phenomena in their sequence and correlations and an illogical proclivity to hasty excogitation. Lister had been a pupil of my class in University College, and had served temporarily as my ophthalmic assistant at the hospital, having, at his own request, obtained permission from me to do so. That Sir Joseph had been studying my Papers on Inflammation with great diligence was evident from the pertinence of his inquiries in conversation with me respecting my observations, in order to obtain by word of mouth further elucidations of the subject. So intent, indeed, was he in his inquiries that he, one day, accompanied me in my walk to the Regent's Park after the hospital visit, *cross-examining* me all the way!

§ 77. In preparing the specimens for the microscope of frogs' webs injected with their own blood to illustrate the state of the blood and the blood-vessels in inflammation which accompanied my Essay,† I applied a saturated solution of common salt on both the dorsal and plantar surfaces of the webs. The first effect of this was constriction of the calibre of the arteries—from branches to trunk—with retardation of the flow of blood in them. Relaxation of their muscular walls quickly supervening, however, the arteries became dilated by distension with the full streams of blood entering them under the influence of the now unimpeded *vis a tergo*. Notwithstanding this free flow of blood in the large arteries, the blood in the extreme vessels of the part to which they led was acted on so strongly and completely by a continued application of the salt, that the red corpuscles at

* I am not sure that Lister quotes in full the title of this Essay, which is: "On the State of the Blood and the Blood-Vessels in Inflammation, as ascertained by experiments, injections, and observations by the microscope." This title, I have been given to understand, was the original dictation of Sir Astley Cooper himself. It defines exactly what it may be considered necessary to know on the subject. In working out the various points for my Essay I kept closely to the requirements indicated; indulging in no excogitations.

† The specimens were deposited in Guy's Hospital Museum, and the special description of them given in the 'Reports' for October, 1850.

length agglomerated together into a mass, which became stagnant and filled the said vessels like an injection of red wax, as above elucidated in the two preceding paragraphs, §§ 75 and 76.

§ 78. Here, it is now to be stated, that when the blood thus became stagnant in the extreme vessels of the part, the further flow in the trunk was so impeded that the stream in it deviated and passed off by a considerable branch arising from it still higher up. In the trunk between this branch and the place where the stasis in the small vessels existed, a collection of plasma was seen with some corpuscles suspended in it, oscillating forwards and backwards. This collection of plasma I recognised as the result of a process similar to that on which the formation of the *coagulum internum* above described, in the proximal segment of a divided artery, depends. By continuing the application of the salt, the web became at last completely injected and fit to be dried and prepared for mounting on slides for the miscroscope.*

§ 79. Here the remark is to be repeated that the inflammatory injection around a lesion of the web in which vessels have been implicated is increased by the application of the salt and continues so. Certain of the preparations above referred in my Essay in 'Guy's Hospital Reports,' represents cases of such increased inflammatory congestion around a wound.

§ 80. In my Essay, "On the State of the Blood and the Blood-Vessels in Inflammation," an exposition of the phenomena attending the establishment of inflammatory congestion in a wounded part of a frog's web, illustrated by drawings from life, constituted the very groundwork on which my further researches were based. Without tracing out, in their sequence and correlations the phenomena in question, no adequate comprehension of the subject could have been obtained. Subsequent observations on a wounded

* See the special description of all this in my Essay in 'Guy's Hospital Reports.'

part of a bat's wing supplied what it was desirable to know regarding the phenomena as they present themselves in a mammiferous animal.

§ 81. In his paper in the 'Philosophical Transactions' for 1858, p. 659, Lister says:—"The effect of arterial *contraction* in producing accumulation and stagnation of corpuscles in the capillaries has been described by Mr. Wharton Jones as occurring in the web of a frog in a state of health, and concludes this allegation of his by excogitating that it was perfectly clear that stagnation of the blood depended on something more than mere contraction of the arteries," omitting, however, a description of the phenomena of that "something more." I do not understand what is here meant by "the arterial contraction" which I am made to say "produces accumulation and stagnation of corpuscles in the capillaries"—whether "*an act of contraction*" or "a state of contraction" of the muscular walls of the arteries with constriction of their calibre. Surely Lister did not mean to say that "an act of contraction of the muscular walls of small arteries of the web of a frog has been indicated by me as exciting a special operation by which stagnation of blood in the capillaries is occasioned." If he did, I must denounce the allegation as an *ignoratio elenchi*. If, however, he meant a state of *contraction* of the *muscular walls of arterioles* with corresponding *constriction of their calibre*, he does not say so, and much less does he specify the phenomena which I describe and delineate as supervening on the constriction—such, for example, as the mode in which the direct flow of blood in the capillaries and venous radicles to which the constricted arterioles lead, is obstructed and replaced by reflux from adjacent vessels in which the circulation is still free. By this omission, therefore, Lister still remains open to the charge of attributing to me what I never said.

§ 82. Since renouncing the excogitation that suspension of nervous influence from the small vessels of a part constitutes a condition for the establishment of inflammatory congestion (§§ 4, 69), I have all along contended that when the calibre of a minute artery of the frog's web or bat's wing becomes

constricted by the contraction of its muscular wall, by what cause soever excited, so that the current of blood is retarded, we observe that red corpuscles accumulate by retention and, aggregating, come at last to block up the capillaries and venous radicles to which the constricted arterioles lead. The accumulation thus arising is augmented by the addition of corpuscles derived by reflux from neighbouring vessels in which the circulation is still free owing to their origin being higher up, as explained in detail, §§ 52–56.

§ 83. Lister, it is above mentioned, excogitates that it was perfectly clear that stagnation of the blood depended on "something more" than mere contraction of the arteries. What that "something more" is, he, however, leaves a mystery under the name of "suspension of animation." He does not even explain what he means by the vague expression of "contraction of the arteries" which he attributes to me, though I never used it. Nay, more, as if to fix a charge of error on me, he adduces an observation of his own to show that accumulation and stasis of corpuscles took place in two or three capillaries unaccompanied by any change in the vascular dimensions—meaning by this that there was no "contraction of the arteries." Perfectly true, but the stasis in this case was owing to a change in the condition of the corpuscles themselves by the action of the morsel of capsicum which Lister himself applied to the web in his experiment; though, in consequence of his inadequate observation, he overlooked the sequence and correlations of the phenomenon.

§ 84. It has been above shown (§ 76), and let it be here repeated, that under the action of a solution of salt dropped on the web of a frog, the full stream of blood in the larger arteries at first escapes, in a great measure, being affected, but that in consequence of the tenuity of the stream in the capillaries, the red corpuscles of the blood flowing therein readily become acted on by the salt which is imbibed into it, so that here and there we may see them aggregated and stagnant. This effect of the imbibition of salt in solution through the capillary wall on the red corpuscles is described and delineated in my Essay in 'Guy's Hospital Reports,' so

often referred to. The direct action of the salt on the red corpuscles was indicated by their becoming of a darker tint and more flattened form. In exemplification of a change in the state of the red corpuscles of the nature just indicated, operating as a cause of stasis, it may be here added that, the effect of carbonic acid gas directed in a minute stream on a spot of the outside of a lung of the frog,* is to cause arrestment of the flow of blood in the capillaries at the place, independently of any change in the vascular dimensions. The pulmonary arteries, it may be here remarked, have only a weak muscular coat, so that they are not liable to undergo any material degree of constriction of calibre.

Notwithstanding this, and the peculiar abrupt ending of the arterioles in the capillaries, Dr. George Johnson maintains his excogitation that the entrance of blood into the lungs in cholera collapse is shut out by an increase of contractile power, generated, we must suppose, for the nonce, whereby the calibre of the vessels is constricted.

§ 85. Besides his excogitation that it was perfectly clear that stagnation of the blood depended on a "something more than mere contraction of the arteries," Lister adds that it also appeared impossible to account for it satisfactorily as a result of the dilatation of the arteries. No doubt, but it is to be added that it could not be accounted for *at all* as a result of dilatation, as I have already shown, except around a wound. But why talk about accounting for anything without observing the phenomena in their sequence and correlations whereby we may come to understand what it is necessary for us to know. By his inadequate observation, Lister necessarily fails to account for what he has before his eyes.

§ 86. We have above seen that, according to Sir Charles Hastings, the appearance presented by the red corpuscles within the vessels of the affected part at the commencement of inflammation in a frog's web, as if fused together into a uniform red mass which is moved sluggishly along, depends

* 'Observations on the Blood' in No. XXVIII. of the 'British and Foreign Medical Review,' published in 1842.

on a debilitated action of the vessels themselves. This *obiter dictum* of Sir Charles Hastings, though merely a rag of the Brunonian theory, has been (it is above mentioned, § 36) adopted by Sir Joseph Lister, and amplified by him into "a suspension of functional activity in the affected tissues, from some injurious influence acting on them, the result of which on the blood therein, is that the red corpuscles acquire a *stickiness* of their surface, owing to which they aggregate together and block up the vessels."

§ 87. This meaningless excogitation of his, Sir Joseph Lister claims to be a scientific discovery by himself of the true cause of the commencement of inflammatory congestion, and boasts that it has received independent confirmation from his subsequent inquiry into the nature of coagulation (Croonian Lecture, Royal Society, 1863, 'Proceedings,' pp. 30–1), which is also no more than an excogitation. We have thus presented to us one meaningless excogitation in support of another, in explanation of phenomena which ought to have been observed and described in their sequence and correlations.

Structure and Functions of the Blood-Vessels.

§ 88. Under this heading Sir Joseph Lister introduces an episode into his paper on Inflammation in the 'Philosophical Transactions' which we have been examining, but for what purpose it is difficult to imagine, seeing that it does not really bear on inflammation, and seeing that he manifests no just comprehension of what he pretends to discuss—a remark, I have above shown, to be applicable to the main subject of his paper. Certainly, whatever the purpose or intention was, the effect of Lister's *would-be criticism,* under the encouraging but misguiding auspices of his Professor, Dr. Sharpey, virtually amounts to slander of my work, in which I traced crucial facts, elucidating vital points in Medical Science. But to return, Lister says: "The minute veins sometimes exhibit great contractility" in the higher animals, as in the irregular constrictions often seen in the mesentery of the mouse and in

the remarkable rhythmical variations in calibre"—("rhythmieal variations in ealibre," let it be noted, is no expression of mine)—"diseovered by Mr. Wharton Jones, in those of the bat's wing" ('Philosophical Transaetions,' 1852). Herein nothing is said of the "structure and funetions" of the minute veins of the mesentery of the mouse nor of the veins in the bat's wing, whilst the aeeounts given in referenee to the minute veins of the mesentery of the mouse and to the veins of the bat's wing are meaningless or short of the truth.

§ 89. The minute veins in the mesentery of the mouse can be seen under mieroseopieal examination, only when the animal is in a moribund state, and the eontraetions which their museular wall is observed to undergo here and there while the intervening parts swell out into varieose dilatations, are indications not of normal function, but only of beginning *rigor mortis*. Constrietion of a small vein in the mesentery of a moribund mouse, as I saw it thus taking plaee, is represented in a figure at p. 556 of the last edition of my 'Ophthalmie Medieine and Surgery.' Herein, eertainly, it may be remarked, there eould be no doubt of the existenee of suspension of "funetional activity"—not, however, in a *greater or less degree*, merely, but to a lethal extent. Sir Joseph Lister, in speaking as he does, omits to deseribe the eonditions under whieh he observed the phenomena, nay, he does not describe the phenomena themselves, either in their sequenee or eorrelations. Surely, *Biologists*, in their experimental researches, do not "often" subject the mesentery of a mouse to mieroseopieal examination, and when they do, it certainly is not with the expeetation of finding the vessels aeting normally.

§ 90. Sir Joseph Lister eouples the muscular eontraetions whieh cause the "irregular constrietions" of minute veins in the mesentery of a moribund mouse with the normal rhythmieal or heart-like eontractions of the veins in the wings of a healthy bat, designating the latter merely under the name of "rhythmieal variations in ealibre" (an expression, whieh is physiologieally *illiterate*), without any referenee to the rhythmieal heart-like contraetions of the museular walls of

the veins causing the constrictions in calibre, which alternate with dilatations, whereby the onward course of the blood is promoted, regurgitation being prevented by valves. The dilatations of calibre depend on ensuing muscular relaxation of the walls of the veins, with elastic reaction of adjacent parts and entrance of blood. According to his own incidental mention, Lister had, in his possession, bats for examination; but he seems not to have studied the phenomena of the circulation in their sequence and correlations. It might have been supposed that Lister, who had previously occupied himself with success in teazing out and disposing for examination under the microscope, the muscular fibres of the tonically contractile walls of vessels generally, would have been curious to ascertain the microscopical characters of the muscular fibres of the walls of vessels, the calibre of which undergoes rhythmical variations! But no! He does not even specially recognise rhythmical contractions of the muscular walls of the veins as the cause of the rhythmical variations of their calibre, much less the propulsive force exerted on the stream of blood.

§ 91. The title of my Paper in the 'Philosophical Transactions' for 1852 is this: "Discovery that the Veins of the Bat's wing, which are furnished with valves, are endowed with rhythmical contractility, and that the onward flow of blood is accelerated at each contraction." This title, though brief, indicates something more than rhythmical variations in calibre, but Sir Joseph does not quote it, so that all his remarks on the subject are meaningless or short of the truth. Nay, worse than this, Lister does not notice the fact, specially insisted on in a postscript to my Paper, that, in the ear of the long-eared bat, which admits of being displayed for examination under the microscope, the veins are found not to be endowed with rhythmical contractility like those of the wing, and that the microscopical characters of the fibres of their muscular coat do not differ from those of the plane muscular fibres of ordinary veins.

§ 92. The microscopical characters of the rhythmically contractile muscular fibres of the walls of the veins of the

bat's wing are pictorially delineated in my paper, in the 'Philosophical Transactions.' This, notwithstanding, and notwithstanding the special description I gave of them as altogether unique, the late Professor Sharpey, who, as Secretary, communicated Lister's paper, under notice, to the Royal Society, had, in an histological annotation to a Students' Manual of Anatomy (the edition which appeared several years subsequently to the publication of my Paper), alleged that the rhythmically contractile muscular fibres of the walls of the veins of the bat's wing do not differ in their microscopical characters from the ordinary plane muscular fibres of veins in other parts of the bat's body—a blunder regarding which I questioned Dr. Sharpey one evening at the Royal Society. His reply was that I had told him so, which I certainly never did. I remember quite well telling him the very opposite fact which I had specially stated in the P.S. to my Paper in the 'Philosophical Transactions,' some years previously.

§ 93. Though the muscular walls of the veins of the bat's wing are rhythmically contractile, the vessels themselves do not "pulsate" like arteries. Arteries pulsate in consequence of the rhythmical distensions of their calibre by the stream of blood rhythmically propelled with acceleration at each stroke of the heart, but their walls are not rhythmically contractile. They are tonically contractile and elastic only. We shall return to this below.

§ 94. The expression "rhythmic variations in calibre" (physiologically illiterate as it is), without any reference to the effect on the flow of blood in the vessels, to designate the rhythmical heart-like action of the walls of the veins of the bat's wing with corresponding constriction, of their calibre has been adopted by Professor Michael Foster of Cambridge (an old pupil of Dr. Sharpey, like Sir Joseph Lister), and persisted in. This blundering, both by commission and omission, on the part of Foster, is very little less excusable than the unfounded utterance of Professor Burdon Sanderson, the Oxford Professor of Biology, that "rhythmical contractions of veins occur in certain animals," or that

meaningless assertion of Professor McKendrick, the Glasgow Professor, viz. that rhythmical contractions of veins "sometimes" take place. (See my Article on the subject in the 'Lancet,' February, 1885.) I do not know whether Professor Burdon Sanderson, instead of demonstrating to his pupils, as it is his duty to do, the real fact in the bat's wing, continues to teach, in the Biological Institute of Oxford,* the meaningless figment that "rhythmical contractions of veins occur in certain animals;" but Professor McKendrick has improved on his previous misrepresentation, when in the new edition of his Physiology, recently published (volume ii., p. 269), he gives utterance to the following elaborate excogitation: "In some rare instances, the blood pressure still acting through the capillaries, the pressure of the muscles and the aspirations of the chest are unable, apparently, to carry on the circulation, and then we (*i.e.* Professor McKendrick himself) find portions of the veins 'pulsating' (?), constituting accessory hearts, as in the 'caudal vein of the eel' (?) and in the veins of the wing of the bat." On this it is to be observed that, as repeatedly said, the caudal vein of the eel does not pulsate, nor is it endowed with rhythmical contractility, nor do the veins of the bat's wing pulsate, though they contract rhythmically. Moreover, it is to be remarked, that the distance of the veins of the bat's wing from the influence of the systemic heart of the animal seems to "account" for the superaddition of the force exerted by the rhythmical contractions of the veins supported by valves. In his meaningless excogitation, merging into fiction, Professor McKendrick adopts the common mistake of confounding rhythmical contraction of the muscular walls of the veins of the bat's wing with pulsation, such as is exemplified in the rhythmical distensions of an artery (not contractions) at each stroke of the heart; thus betraying gross ignorance of

* Harvey would have been delighted to know the real facts in Nature which Burdon Sanderson here so ignorantly glosses over. When Warden of Merton College, Oxford, Harvey, could he have foreseen that a Fellow of the College and Professor of Biology in the University cared so little for crucial facts, would have been mortified.

the facts and phenomena he is pretending to describe to his *student-readers*. The walls of the caudal vein of the eel are not endowed with rhythmical contractility, nor does the vessel pulsate. Though lymph is rhythmically propelled into it by the caudal lymph heart, the caudal vein is not distended to pulsation thereby, because the channel of the vein, like that of other veins, progressively increases in width in its course.* Besides this, the stream of lymph propelled into it by the caudal heart through its short narrow duct, is so small and so little forcible that even an equally sized artery could scarcely be distended to pulsation by it. It is something deplorable that a student should be taught in his text-book, which he is expected to study and believe, under the terror of examination, that the vein in the tail of the eel which receives the lymph from the caudal heart serves the purpose of an accessory blood heart, whilst the caudal lymph heart itself is actually ignored. As to the veins in the wing of the bat, which are furnished with valves, though they are endowed with rhythmical contractility, and thereby serve as accessory blood hearts, they do not pulsate in the sense that an artery pulsates. In short, let it be repeated: the action of the veins of the bat's wing is a heart-like action by which the flow of the blood is rhythmically accelerated in aid of the force of the heart of the general system from behind. The vein could not act like a heart and pulsate like an artery at the same moment. The pulse of an artery is synchronous with the contraction of the ventricle of the heart. No other example is as yet known, in any vertebrate animal, of *veins endowed with rhythmical contractility of their walls, and serving as accessory blood hearts.*† There being valves in the veins in the bat's wing preventing regurgitation, the

* See below, the section on lymph hearts.

† I have always considered it probable that in the very long tails of some animals, and even in our toes, the extreme veins might be endowed with rhythmical contractility of their wall, but in the few microscopical examinations I have been able to make, on the point, I have not discovered in the muscular walls characters similar to those presented by the muscular coat of the veins of the bat's wing (§ 92).

blood necessarily continues in its course, which is aeeelerated at each of the rhythmieally recurring contraetions. The eontractions, it may be mentioned, take plaee eleven or twelve times in a minute.

§ 95. McKendriek's blunder about the eaudal vein of the eel, which he has evidently borrowed from Foster, would be a manifestation of ignorance and ineapacity, something astounding, if we could allow ourselves to suppose that he had ever seen the eaudal lymph heart of the eel in action, and the propulsion of lymph from it into the caudal vein. It is evident, however, as just remarked, that what the Glasgow Professor says is merely borrowed from the Cambridge Professor, who doggedly repeats his blundering as it appeared in a previous edition of his book, and which was commented on in my Article in the 'Laneet' five years ago. Nay, regardless of the injury which must result to the minds of students of his text-book by telling them what is not the fact disclosed by observation of phenomena, Professor Michael Foster says that "rhythmic variations" of ealibre, due to contractions, may be seen elsewhere than in the veins of the bat's wing. The "elsewhere," which is here referred to, seems to be the caudal vein of the eel, as if its walls were endowed with rhythmical contractility (with which they are not), and as if the vessel were the seat of pulsations like an artery (of which it is not); at the same time, the Cambridge Professor makes no mention of the state of the blood in the vein, nor the propulsion of lymph from the caudal lymph heart into the vessel through a small duct, nor the remarkable phenomenon attending this propulsion, viz. the cutting across of the blood stream in the vein by the small lymph streams which are propelled in rhythmieal suecession from the lymph heart into the vein.

§ 96. *Contraction* of the walls of arteries with *constriction* of their calibre is in no ease rhythmieal, nor propulsive of the blood from trunk to branches;* on the eontrary, the eontrae-

* When a small artery of the web of a frog's foot, displayed under a microscope, is cut across, we have seen that while the upper segment becomes constricted trunkwards, the lower segment becomes constricted in

tion is propagated in a continuous retrograde direction from branches to trunk, causing a reflux of blood. In the rabbit's ear (as will be stated in detail below), the main artery when it is constricted may be seen not only no longer transmitting blood to the capillaries, but itself completely emptied, so that the ear is bloodless and cold. In the course of our observations of the phenomena of the circulation in the web of the frog's foot or bat's wing displayed under the microscope, we sometimes see a small artery or two become constricted so that the flow of blood in them is arrested—not arrested merely, but actually regurgitated. It is worthy of remark that in such cases, when an artery was seen thus beginning to close in, the animal struggled, so that further observation was for the time interrupted. When the animal became quiet, and its web could be again displayed under the microscope, the calibre of the artery was, perhaps, found still constricted, but its walls soon relaxing, the vessel became dilated by distension with the direct stream of blood which began again to flow. It is, further, to be particularly noted that there is nothing rhythmical in these constrictions and dilatations of the arteries, though it has been alleged that there is; thus, the late Professor Rolleston, of Oxford, attributed such an allegation to Lister. On this, I remarked, at p. 88 of my volume on 'Injuries of the Spine and Head' (1869), that in my Essay, "On the State of the Blood and the Blood-Vessels in Inflammation" ('Guy's Hospital Reports' for 1850), there is an account at p. 7, of tonic contraction of walls with constriction of calibre, which arteries of the frog's web are sometimes seen to undergo. Of this Professor Lister was well aware when he wrote eight years subsequently. I am quite sure, therefore, that in his Paper in the 'Philosophical Transactions' for 1858, there is no expression calculated to convey the idea that Rolleston attributed to him; and,

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a direction branchwards, squeezing the blood onwards, but this is merely for a few seconds, and the artery remains constricted only at the place of section. Subsequently when the vessel contracts below this, it does so trunkwards as usual.

certainly, that Lister does not designate the contractions of the walls of the arteries causing the constrictions of their calibre as rhythmical. In my Paper in the 'Philosophical Transactions' for 1852, "On the discovery of the Rhythmical Contractility of the veins of the Bat's Wing," I refer at p. 133 to the non-rhythmical contractions of the walls with constriction of calibre which the small arteries of the bat's wing may be seen to present, as similar to those of the arteries of the frog's web.

Tonic Contractions of Wall with Constrictions of Calibre of the Main Artery in the Rabbit's Ear.

§ 97. In my Paper, "On the Rhythmical Contractility of the veins of the Bat's Wing," in the 'Philosophical Transactions' for 1852, I refer in a note to the tonic constrictions of the main artery in the ear of a rabbit which I observed to take place occasionally in a manner similar to that in which the phenomenon presents itself in an artery of the web of a frog's foot or bat's wing. These constrictions of the artery of the rabbit's ear which take place, at short but irregular intervals, have nothing rhythmical in them, any more than the constrictions of the arterioles from tonic contraction of their walls above mentioned, as seen to occur now and then in the frog's web or bat's wing.

§ 98. Dr. Schiff, of Frankfort, published a Paper, entitled "Ein accessorisches Arterienherz bei Kaninchen," in Vierordt's "Archiv der physiologischen Heilkunde," Band XIII., 1854, pp. 523–7 (that is two years subsequently to the appearance of my Paper in the 'Philosophical Transactions,' "On the Rhythmical Contractility of the veins of the Bat's Wing"). Herein, Dr. Schiff strangely misinterpreted the phenomenon of the tonic constrictions of the main artery of the rabbit's ear, whereby the blood, so far from being accelerated in its onward course, is positively made to regurgitate from branches to trunk, so that the artery becomes empty and the ear bloodless and cold. Notwithstanding that the simply tonic character of

the contractions of the artery of the rabbit's ear is so obvious, Dr. Schiff's misconception that they are rhythmical has actually been taken up by distinguished Physiologists, such, for example, as Professor Rudolph Virchow, of Berlin. No doubt, the main artery running up the middle of the rabbit's ear pulsates under ordinary circumstances, like other arteries, in consequence of the increased distension with blood at each stroke of the systemic heart, but such pulsations, of course, can no longer take place when the vessel is tonically constricted to closure, and the blood is regurgitated from branches to trunk, in opposition to *vis a tergo* from the cardiac impulse.

§ 99. Notwithstanding its incredibly stupid character, the blunder under notice is still repeated. Of all men, the Professor of Biology in the University of Cambridge, who is also Physiological Secretary of the Royal Society, though he appears to have examined the rabbit's ear and noted its bloodless and cold condition during the time the artery is in the state of tonic constriction to closure, has shown himself incapable of interpreting the phenomena. There being no valves in the artery of the rabbit's ear, any more than in other arteries, the effect of constriction of its calibre by the tonic contraction of its wall, propagated as it is from branches trunkward, on the flow of blood is necessarily *regurgitation* as indicated by the attendant phenomena. This, however, has been entirely overlooked; as has also the fact that when relaxation of the muscular wall of the vessel supervenes and the flow of blood permitted again to take place freely, the ear becomes red and warm as in blushing. Thus, though both Harvey and Bacon were originally Cambridge men, their scientific caution against admitting any phenomena in Nature without observation, has not been imitated by Michael Foster. Improving on the blunder, Sir William Savory, a late President of the Royal College of Surgeons and Hunterian Orator, in his edition of Kirke's 'Manual of Physiology,' tells his student-readers that the *veins* of the rabbit's ear had been discovered by Dr. Schiff to possess rhythmical contractility, whereby

the flow of blood in them is expedited, as in the case of the rhythmically contractile veins of the bat's wing!

§ 100. In a different form of blundering, Schiff's "discovery" is represented in the treatise on Physiology by Professor Landois, of Greifswald, to be that the veins of the bat's wing pulsate. Such a manifestation of illiteracy in his own subject, and culpable neglect of the most ordinary painstaking on the part of a German author, I never expected to see. The book has been translated into English by Professor Stirling, of Manchester, who makes the utterances of the German Professor to stand out in such a way as to be still more formally meaningless and contrary to truth.

Of the Systemic Arterioles and their Transition into the Corresponding Capillary Network.

§ 101. In my Essay, "On the State of the Blood and the Blood-Vessels, &c.," in 'Guy's Hospital Reports' for 1850, I describe and delineate (Plate IV.) the systemic arterioles, as observed in the frog's web. The arterioles into which the arteries gradually branch, terminate in the capillary network —one extreme arteriole in a corresponding capillary—the capillary being, perhaps at the moment, of wider calibre even than the arteriole, if the latter be constricted by contraction of its wall. The thickness of the wall of the arteriole depends on its muscular coat, and when this is in a state of contraction, the thickness is increased, while the calibre of the vessel is correspondingly constricted. In 'Guy's Hospital Reports,' for October, 1850, and the 'Philosophical Transactions' for 1852, I have described small arteries in the frog's web and bat's wing as becoming constricted to such a degree, owing to contraction of their muscular coat, that their calibre is for the time closed, so that the stream of blood is wholly interrupted. In this case we can see the thickening of the muscular coat take place by the contraction which it undergoes. This is obviously not an example of

muscular hypertrophy any more than the increase in thickness and hardness of the biceps muscle when we bend our arm. If a minute piece of an artery, with its muscular coat thus contracted and its calibre correspondingly constricted, be cut out from a frog's web or bat's wing, the muscular coat will be seen under microscopical examination still in a thickened state—not hypertrophic—the contraction in this case merging into the contraction of *rigor mortis*.

Of the Pulmonary Arterioles and their Entrance into the Corresponding Capillary Network.

§ 102. The systemic arterioles, it has been just stated, have strong muscular walls, by the contraction of which their calibre undergoes constriction, sometimes even to closure-resisting *vis a tergo*, with the result of causing not only interruption of the direct flow of blood to a part or arrestment altogether, but even reflux, though, as above pointed out, the capillaries and venous radicles beyond may be seen to become filled by regurgitation from neighbouring anastomosing arteries, not so constricted. In fainting, there is more or less general constriction of arterioles, so that the surface of the body is pale and cold, the blood being regurgitated in the arteries from branches to trunk; the retrograde arterial contraction overcoming weakened cardiac action. Though the cerebral arterioles may have a less strongly muscular coat, swooning appears to be owing to a similar constriction of their calibre and regurgitation of blood trunkwards. On one occasion, lying in bed weak and ill, I made an effort to rise, whereupon a swooning sensation began to come over me. I, however, contrived to lay myself back, so that the faintness passed off. At the commencement of this fit, I was sufficiently conscious to be able to compare the faintness with what would be the effect of reflux of blood from the arterioles trunkwards. Herein, I am sure, there was no incongruous *ægri somnium* on my part.

§ 103. To return: The extreme ramifications of the pul-

monary artery have mueh less strong museular walls than those of the systemic arteries, and are not observed in the lung of a frog or salamander, viewed under the microscope, to undergo much, if any, eonstriction of calibre, so that the flow of blood in the capillary network of the lungs is not found liable to any such interruption as that just mentioned in the capillaries of the general system. Obstruction of the circulation in the capillaries of a frog's lung, however, is seen to occur from stagnation of aggregated red corpuseles when the due aëration of the blood is prevented. Thus, as I long ago showed (in the 'British and Foreign Medical Review,' 1842), when a slight stream of earbonic acid gas was directed on the lung of a frog, displayed under a microscope, the flow of blood was arrested in the vessels of the part acted on in consequenee of the aggregation and stagnation of the red corpuscles, which became darker in tint and more flattened in form.

§ 104. At a meeting of the Royal Medical and Chirurgical Society a few years ago, it was contended by Dr. George Johnson, the President, that in cholera eollapse the arrestment of the flow of blood in the capillaries of the lungs is owing to constriction of the pulmonary arterioles to closure of their calibre by contraction of their muscular walls. In opposition to this excogitation, I observed, in a postscript to my Paper in the 'Lancet' for July 18th, 1885, entitled: "Remarks on the Circulation of the Blood," that the extreme ramifications of the pulmonary artery have much less strong muscular walls than the extreme ramifications of the aortie system, and are not observed in the lung of a frog or salamander under the microscope to undergo much, if any, constriction of calibre. Against this objection to his exeogitation, Dr. George Johnson protested in the 'Lancet' for August 1st, 1885, but as he had evidently not studied by direct observation the sequence and eorrelations of the phenomena in Nature, I suggested to him in reply to devote some prolonged attention to the mieroscopical examination of the state of the blood and the blood-vessels in the lung of a frog or water-newt before discussing the question further.

As Dr. Johnson appeared not to have repeated the experiment of directing a slight draught of carbonic acid gas on a part of the frog's lung, displayed under a microscope, so as to observe the effect of deoxygenising the blood in the capillaries, I also suggested to him a study of this most important point. I might further have instanced, which I now do, the enormous engorgement of the gills with impure blood which takes place in a small eel, kept out of the water, during the time the caudal heart is under microscopical examination.

§ 105. In conclusion of my reply to Dr. Johnson's protest in the 'Lancet,' I drew attention to the peculiar abrupt manner in which the pulmonary arterioles open into the capillary network, so that the flow of blood therein is like the spreading rush of streamlets from the nozzle of a watering-can with a plain or flat rose. This peculiar abrupt termination of the pulmonary arterioles in the capillary network, and equally abrupt commencement of pulmonary venules by the abrupt inosculation of capillaries, as seen in the frog's lung, are represented with wonderful accuracy by Marcello Malpighi in the engraving illustrating his work 'De Pulmonibus.' This figure, indeed, is decisive of Malpighi's being the discoverer of the capillary system, whereby he filled up the blank in Harvey's demonstration of the circulation. Malpighi's figure, it may be stated, is even more to be relied on than his verbal description.

§ 106. Without being aware, apparently, of Malpighi's discovery, Dr. Küttner, of Heidelberg, gave a very full account of the mechanism of the extreme circulation in the frog's lung (Virchow's 'Archiv,' vol. lxi., p. 21, 1874). "The origin of very narrow tubes from relatively wide arteries; the extent of the capillary network; also, the relatively wide veins into which the capillaries open"—being all distinctly pointed out. At the same time, Dr. Küttner showed how the great rapidity of the flow of blood in the frog's lung is owing to this arrangement. Again, in vol. lxxiii., p. 476, of Virchow's 'Archiv' for 1878, Dr. Küttner enlarges on the mechanism of the pulmonary circulation in a mammiferous animal. In

Malpighi's work, 'De Pulmonibus,' there is an account, with a figure of a microscopical examination, of the vessels of the mesentery of the frog, but no small vessels intermediate between arteries and veins are represented similar to what he delineated in the lung; though it is generally supposed that capillaries were there described. Malpighi's delineation of the vessels of the frog's mesentery is as true to nature in showing *no* capillaries, as his delineation of the vessels of the frog's lung is in *showing capillaries.* I long ago insisted on the fact that there are no capillary vessels in the mesentery of the frog, the only vessels being arteries going to and veins returning from the *capillary system of the intestine,* with here and there arterioles opening directly into venous trunks. These arterioles were seen, but mistaken by the late Professor Theodore Schwann for capillaries with muscular walls. Capillaries, he forgot, do not open into venous trunks, but only into venous radicles.

Mechanism of the Propulsion of Lymph from Lymphatic Hearts into Veins.

§ 107. The efferent vessel of a lymphatic heart is a short duct, through which the lymph is propelled into a venous trunk. Nothing like a vein arises from a lymphatic heart as has been commonly supposed. The *receptaculum chyli* may be compared to a lymph heart; the thoracic duct, though so long, to the efferent vessel or duct of a lymph heart; and the entrance of the thoracic duct into the subclavian vein to the entrance of the duct of a lymph heart into its corresponding venous trunk. It would, therefore, be not more absurd to say that the subclavian vein arises from the *receptaculum chyli,* than to say that the venous trunk, situated on the pelvic side of the large transverse process of the third vertebra in the frog, and into which lymph is propelled from the corresponding anterior lymph heart of that animal, actually arises from the said anterior lymph heart.*

* See the diagram *infra.*

§ 108. In the tail of a small eel displayed under a microscope, we see that the efferent vessel of the lymph heart, which is there situated, is a short duct opening into one of the two trunks which, by their junction, form the great caudal vein.* The lymph propelled by each stroke of the lymph heart through this duct into the venous trunk mentioned, cuts across the stream of red blood therein, so that an appearance is occasioned as if separate drops of red blood were actually propelled from the heart. Mislead by this deceptive appearance, Dr. Marshall Hall, who discovered the organ, took the lymphatic heart of the eel's tail for an auxiliary blood heart, not having recognised the colourless lymph as the exclusive issue of its contractions and the simple cutting across thereby of the red blood stream in the vein at each stroke.

§ 109. The caudal heart of the eel, then, is a lymphatic heart and propels lymph by a short valvular duct into one of the two large veins which unite to form the great caudal vein; but no vein arises from the heart, and as little does a vein arise from either of the anterior lymphatic hearts of the frog, as the late Professor Müller, of Berlin, and Panizza, of Pavia, supposed. The jugular vein of the frog, which is very black from the quantity of pigment deposit in its walls, was originally observed by Dr. Marshall Hall, but he took it for an artery on account of the movements which it exhibits, which, however, are not pulsations, but are backward and forward movements of the vessel as a whole in the direction of its length. Noting that these movements are synchronous with the contractions of the anterior lymphatic heart of the corresponding side, and recognising the vessel to be a vein, Müller thought that the movements are pulsations caused by the propulsion of lymph into the vein by the heart. A little reflection, however, might have suggested to that distinguished discoverer of the lymph heart, that as veins go on to increase in width, the vein under notice could not be distended by the sudden propulsion of lymph into it, even if

* See my Paper in the 'Philosophical Transactions' for 1868, p. 675, entitled: 'The Caudal Heart of the Eel, a Lymphatic Heart.'

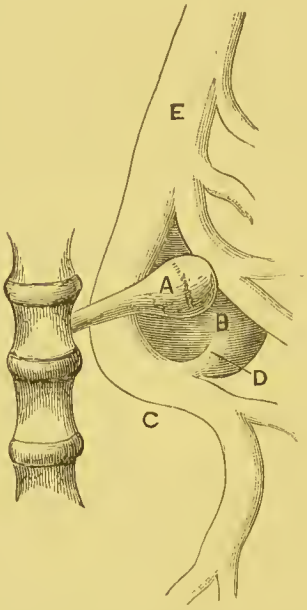
the vein had had its origin from the heart, and consequently that it could not be made to pulsate in the manner an artery is made to pulsate. Moreover, had Professor Müller known that it is a small duct only through which a lymphatic heart propels lymph into a vein, he would still less have supposed that pulsation of the vein could be caused by the propulsion of lymph into it through such a narrow channel.

§ 110. It is thus seen, that in the tail of a small eel displayed under a microscope, the caudal vein is *not* endowed with rhythmical contractility of its wall like the veins of the bat's wing, and that the rhythmical propulsion of lymph into it from the rhythmically contracting caudal heart does not cause pulsation of it. In the case of an anterior lymph heart of the frog, not only does no vein arise from it, but the venous trunk into which its duct opens is not, as was supposed by Müller, the jugular trunk which is seen oscillating backwards and forwards as a whole in the direction of its length; it is, on the contrary, a vein (of which, indeed, the jugular is the trunk) situated, as above mentioned, on the other side—the pelvic side—namely, of the large transverse process of the third vertebra.* Moreover, the lymph propelled, as before mentioned, through the small duct leading from the heart into this vein, does not cause it to pulsate. Thus, I saw under microscopical examination of the left anterior lymphatic heart, that the lymph, on entering the vein from the duct at each systole, caused no pulsatory distension of the vessel, but merely pressed the stream of red blood gently aside, at the same time sweeping it onward in front, though arresting its flow, for the moment, behind. In this case the stream of lymph from the lymphatic heart did not cut the stream of red blood in the vein right across, in the manner the stream of blood in the vein of the eel is cut across by the stream of lymph propelled into it by the caudal heart, a difference of no fundamental significance, but owing merely to the less degree of force with which the lymph is propelled in the former case, and to the difference in the mode of ramification

* See the diagram *infra*.

of the vein in the latter. The vein into which the lymph is propelled from an anterior lymphatic heart of the frog, it is to be further stated, is *not* endowed with rhythmical contractility of its wall, calculated to act as a propelling force, any more than it is, itself, made to pulsate by the propulsion of lymph into it.

The Paper entitled, "On the Phenomena observed to attend the Propulsion of Lymph from an anterior lymphatic



Description of the diagram (magnified three or four diameters).

A. The large transverse process of the third vertebra. B. The lymphatic heart. C. The vein into which the heart propels the lymph. D. The duct by which the heart opens into the vein. E. The large venous trunk (the pigmentation not represented), a continuation of C, which runs up as if from the lymphatic heart.

heart into a vein in the Frog," just analysed, was communicated to the Royal Society in 1868. On account of its fundamental importance as the first record of a crucial fact, whereby a glaring but current mistake is corrected, I here add extracts from the Paper explaining the mode of procedure in the research.

I. *Description of the phenomena.*

§ 111. It was shown by the late Dr. Marshall Hall that by plunging a frog into water of a temperature from 110° to

120° Fahreneit, the animal is killed as regards sensation and voluntary motion, without stoppage of the eirculation. A frog, having been thus treated and rendered so far dead, I laid the thoraco-abdominal eavity completely open and pushed the viseera to one side. On looking into the other side—the left, for example—thus emptied of its eontents, and direeting attention to the niehe behind and below the extremity of the large transverse process of the third vertebra, the pulsations of the anterior lymphatie heart of the said side were seen with the naked eye. By now removing the skin of the baek from over the seapular region, the posterior part of the heart admitted of being examined under the microseope by transmitted light, and the phenomena attending the propulsion of lymph from it into a vein at its posterior border, observed.

§ 112. Here I would remark, in passing, that in laying open the thoraeo-abdominal eavity of the animal, eare is to taken not to wound the blood heart and great vessels; for though the lymphatie hearts pulsate independently of the presence of the blood heart, it is a neeessary eondition for the eontinuanee of the whole phenomena that the circulation of the blood should be going on. In making my observations, I found it more eonvenient to use a simple than a eompound microseope. Viewing then the parts from the inside of the thorax with a lens of half-an-ineh foeus, I observed that when the lymphatie heart eontraeted, the lymph stream propelled through its duet into the vein swept before it the blood-eolumn in this vessel. The lymph, thus propelled, oecupied the whole of that part of the vein into which the heart opens, so that the vessel appeared for the moment quite eolourless at the plaee. As soon, however, as diastole of the lymphatic heart supervened, the flow of blood from behind beeame re-established, and the lymph, filling the vein at the plaee, was, in its turn, driven onwards, and mingled with the general stream. The vein, thus beeoming refilled with blood, now appeared red. Systole of the heart, however, again ensuing, the lymph stream propelled into the vein swept onwards the blood in that vessel as before, whilst the

flow of blood from behind was arrested; and so the same series of phenomena was repeated.

§ 113. It is thus seen that the phenomena attending the propulsion of lymph from an anterior lymphatic heart of the frog into the vein with which it communicates by a small duct, are essentially similar to those attending the propulsion of the lymph from the caudal heart of the eel into its corresponding vein. In the frog, the lymphatic heart contracts about sixty times in the minute according to Müller, while the caudal heart of the eel contracts about 160 times according to Hall. This great difference in the number of pulsations a minute I have noted, though I did not take the pains to count.

II. *Of the vein into which the anterior lymphatic heart propels the lymph, as just described.*

§ 114. The branches of the vein at the posterior border of the heart which receives the lymph therefrom, as above described, come from the lateral part of the thoraco-abdominal wall. After receiving the short duct from the heart, it turns behind the large transverse process of the third vertebra, and passes forward along the inner to the anterior border of the lymphatic heart to unite with veins on the outer border of the said heart. The large venous trunk thus resulting (blackish-looking from the quantity of pigment deposit on its outer coat), runs up as if from the heart, and is described by Müller as the jugular. The veins joining it from below are bound in a manner to the outer border of the lymphatic heart by the surrounding tissues.

§ 115. At each systole of the lymphatic heart, I observed that the blackish vein was drawn as a whole backwards in the direction of its length, and that at each diastole, the vessel moved forwards by recoil into its previous position. This rhythmical backward and forward movement of the vein, longways, appeared to be owing to this: that the heart, bound as just explained, to the blackish vein, through the medium of the surrounding venous roots, in contracting, drags the

vein towards it, and that when relaxation of the heart succeeds the contraction, elasticity of the surrounding structures occasions the recoil.

§ 116. According to Professor Johannes Müller,* the large blackish venous trunk in the neck issues from the lymphatic heart anteriorly. That this is not the case, dissection and examination of the parts from the dorsal aspect† under the simple microscope have satisfied me. I would, however, remark that it is not by dissection, but only by observation, under the microscope, of the direction of the streams in them, that the anatomical relations of such vessels can be correctly determined.

§ 117. Professor Müller says that the vein in question becomes turgid each time that the lymphatic heart contracts ('Physiology,' vol. i., p. 293). This could only be by injection of lymph into the vessel from the heart. But there is no such turgidity produced by the injection of lymph through the small duct of the heart into the vein as I have above shown, and I cannot help thinking that Professor Müller mistook the dragging of the vein towards the heart for turgidity of it. The late Dr. Marshall Hall mistook the vein for an artery, and considered the movements of the vessel as pulsations of it in that character.

* 'On the existence of four distinct hearts having regular pulsations, connected with the lymphatic system in certain amphibious animals, 'Philosophical Transactions' for 1833, p. 92.

† After such dissections, I have found the lymphatic heart contain a globule of air; which, no doubt, had been drawn in through an opening made by cutting into the lymph spaces.

APPENDIX.

List of Articles on the Circulation, which have appeared in the 'Lancet' in the course of the Decade from 1880–1890; with Extracts, comprising Incidental Strictures on the prevailing Misinstruction of Students of Medicine on the subject.

I.—'Alleged Emigration of White Blood-corpuscles from the Interior of small Vessels by boring through their Walls.' A Remonstrance, addressed to Professors of Physiology and Pathology against teaching that the White Corpuscles of the Blood escape from the interior of small Vessels, until they have verified it scientifically by actual Observations of their own as a fact in Nature.

I*a*.—'Supplement to this Remonstrance, pointing out Professor Cohnheim's change of opinion regarding the mechanism, while Dr. Binz, of Bonn, upholds the old opinion.'

An additional remonstrance recommends students not to believe what their text-books and Professors tell them, but to require the actual demonstration of facts in Nature.

II.—'Dilatation of the Calibre of small Arteries. Is it a fact in Nature, disclosed by "experimental research," that dilatation of the calibre of small arteries is primary, and owing to an active expansion of their walls under the influence of special vaso-dilator nerves?' An Inquiry addressed to Physiological Authors, Professors, and occasional Orators.

III.—'Remarks on the Circulation of the Blood. Historical Notice of the discovery that the veins of the bat's wing, which are furnished with valves, are endowed with rhythmical contractility, whereby the blood is assisted onward on its course to the heart.' A Protest against efforts made to ignore a crucial fact in Nature.

IV.—'Remarks on the Circulation of the Blood. Mechanism of the establishment of vascular Congestion: an Experimental Research.' Dedicated to Students of Medicine.

V.—'Mechanism of the Action of the Heart, &c. A Discourse on Harvey's exposition of the mechanism of the heart and great arteries, Malpighi's discovery of the capillary system, subsequent supplementary

elucidation of the "artificium admirabile" of the circulation in the extreme vessels, and the mechanism of the propulsion of lymph from lymphatic hearts into veins.' Dedicated to the President and Members of the General Medical Council.

It has lately been ordained by the General Council of Medical Education that Logic be an optional subject for students about to commence the study of Medicine. This is a wise decision; but it is to be observed, that without a knowledge of well-defined facts in Nature to serve as *data*, logic would be worse than useless. The more exact logical reasoning is, indeed, the more false is the conclusion if the premisses are not sound. The General Council should, therefore, begin with the Professors, and exhort them to teach their students facts, and the correlations thereof, in language logically correct. Students would thus acquire a knowledge of logic practically at the same time they were being instructed in the special subject engaging their attention; and their minds, instead of being unduly taxed and strained, would thereby be positively strengthened, while their labours would be rendered more easy and agreeable. The desirability of improvement on the part of Professors in a scientific knowledge of well-made-out facts in Nature, and in a logical method of communicating them to students, either in books or in demonstrations and lectures, is very evident from the blundering exposed in this and my previous articles. If the General Council of Medical Education will sift the so-called "advancing mass of biological knowledge" with which the rising generation of teachers in our medical institutions is said to be grappling, they will probably find that it comprises much chaff and little grain, and that the too often meaningless, when not false, teachings obtruded by the said biologists on their pupils must, indeed, prove an actual source of distraction to the young men under any and all circumstances.

The study of the mechanism and action of the vessels in the extreme circulation of the blood, as observable in Nature, is so inaccurately prosecuted, that the science of physiology in its applications to Medicine, as taught to students, is by no means in such a state of advancement in the curriculum of the schools as it ought to be.

VI.—'Peroration to my Reminiscences of Fifty Years' Struggle, in the footsteps of William Harvey, to search out crucial facts in promoting physiological knowledge in its relation to Medical Science.'

Herein I protest against the incongruous teachings by which the minds of students of Medicine are distracted, and to urge a plea for their better instruction in a knowledge of fundamental facts. Such, for example, as the observable mechanism and action of the vessels in the extreme circulation of the blood, regarding which their Professors seem to be ignorant, either from incapacity or wilfulness.

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